Bacteria TMDLs for Popes Head Creek, Broad Run, Kettle Run, South Run, Little Bull Run, Bull Run and the Occoquan River, Virginia

Submitted by

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Executive Summary

This report presents the development of Bacteria TMDLs for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds, located in the Potomac River Basin. Segments of Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River were listed as impaired on Virginia's 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998, 2002, 2004) because of violations of the state's water quality standard for fecal coliform bacteria.

Description of the Study Area

Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River all flow into the Occoquan Reservoir. The impaired segments located on Broad Run are within Prince William County with the upstream section located in Fauquier County and the downstream section located in Manassas City. The impaired segments on Kettle Run, Little Bull Run, and the Occoquan River are also located in Prince William County. The majority of the South Run impaired segment is located in Fauquier County with the downstream section located in Prince William County. The impaired segment located on Bull Run borders both Manassas City and Fairfax County and the Popes Head Creek impaired segment is located within Fairfax County. Bacteria TMDLs have already been approved for two impaired streams within the Occoquan watershed, Cedar Run and Licking Run which flow into the Occoquan River. The results of the approved bacteria TMDLs are incorporated in model development.

Approximately 40 percent of the entire drainage basin is located in Prince William County, 36 percent in Fauquier County and 17 percent in Fairfax County; the remainder of the watershed is divided among the counties of Stafford and Loudoun (less than 1% and 5%, respectively) and the cities of Manassas, Manassas Park, and Fairfax City (2%, less than 1%, and less than 1%, respectively). As shown in **Figure 3-1**, the major highways that run through the watershed are interstate Route 66, U.S. Route 15, and U.S. Route 29. The majority of the major roadways are concentrated in the northeastern section of the watershed in Prince William and Fairfax Counties.

Impairment Description

Segments of Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located the Occoquan River Basin in northern Virginia in the hydrologic unit (HUC) 0270010. The total length of these nine segments is approximately 37.5 miles (including the addition to the Occoquan River impairment). The impaired watersheds include portions of Fairfax County, Fauquier County, Loudon County, Prince William County, Fairfax City, Manassas City, and Manassas Park City.

Three segments of Broad Run were identified in VA DEQ's 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The first impaired segment of Broad Run (VAN-A19R-01) is 7.26 miles long and begins at the confluence to Rocky Branch and continues down stream to confluence to Cannon Branch. Four of 19 samples (21.1%) collected at the listing station (ABRU007.58) between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 mL. The second impaired segment on Broad Run is impaired for 1.51 from the confluence of an unnamed tributary to Broad Run at rivermile 21.43 and continues downstream to the start of Lake Manassas (VAN-A19-R-02). Seven out of 18 samples (38.9%) collected the listing station (1ABRU020.12) between January 1, 1998 and December 31, 2002 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL). The third segment of Broad Run is impaired from the confluence of Mill Run continuing downstream to the confluence of Trapp Run with Broad Run (VAN-A19R-05). Two out of 5 samples collected at station (1ABRU026.40) at the Route 628 Bridge between January 1, 1998 and December 31, 2002 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL).

The impaired segment of Kettle Run (VAN-A19R-03) begins at an unnamed tributary to Kettle Run approximately 0.08 river-miles upstream of Route 708, downstream to its confluence with Broad Run. Eight of 20 samples (40%) collected between January 1, 1998 and December 31, 2002 at the listing station (1AKET0008.0) exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL).

The impaired segment of South Run (VAN-A19R-04) begins on South Run downstream of Lake Brittle and continues downstream to its confluence to Lake Manassas (Broad Run). Five out of 18 samples (27.8%) collected at listing station (1ASOT001.44) between January 1, 1998 and December 31, 2002 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL).

A segment of Popes Head Creek is also impaired from the confluence of Piney Branch to Popes Head Creek approximately 0.25 river-miles downstream of Route 660 (VAN-A23R-02). The instantaneous fecal coliform bacteria standard of 400 (cfu/100mL) was exceeded at listing station (1APOE002.00) for 3 out of 20 samples (15%) collected between January 1, 1998 and December 31, 2002.

The impaired segment of Little Bull Run (VAN-A21-R-01) begins at the confluence of Catharpin Creek to Little Run approximately 0.55 river-miles upstream of Route 704, downstream to its confluence with Lick Branch. Two out of 17 samples (12%) collected between January 1, 1998 and December 31, 2002 at station 1ALII003.97 were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL).

The impaired segment of Bull Run (VAN-A23R-01) begins at the confluence of Cub Run to Bull Run to its confluence with Popes Head Creek. Four out of 34 samples (11.8%) collected between January 1, 1998 and December 31, 2002 were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL) at listing station 1ABUL010.28.

A segment of the Occoquan River is also impaired due to fecal coliform. This segment, VAN-A20R-01, begins downstream from the Lake Jackson impoundment and extends downstream to the confluence of Purcell Branch to the Occoquan River. This segment is currently 1.61 miles but based on a review of the data collected at Prince William Parkway, the total impaired segment will be 5.01 miles in 2006. Between January 1, 1998 and December 31, 2002, four out of 16 samples (25%) were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL) at listing station 1AOCC024.74.

Applicable Water Quality Standards

At the time of the Bacteria TMDLs for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River listings, the Virginia Bacteria Water Quality Standard was expressed in fecal coliform bacteria; however, the bacteria water quality standard has been recently changed and is now expressed in *E. coli*. Virginia's bacteria water quality standard currently states that *E. coli* bacteria shall not exceed a geometric mean of 126 *E. coli* counts per 100 mL of water for two or more samples over within a calendar month or an *E. coli* concentration of 235 counts per 100 mL of water at anytime. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in *E. coli* by converting modeled daily fecal coliform concentrations to daily *E. coli* concentrations using an in-stream translator. This TMDL was required to meet both the geometric mean and instantaneous *E. coli* water quality standard.

Watershed Characterization

The land use characterization for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds watershed was based on land cover data from both the Northern Virginia Regional Commission (NVRC) 2000 Land Use Dataset, and the 1992 USGS National Land Cover Data (NLCD). The NVRC dataset was the most recent available land use dataset, and was also utilized in order to be consistent with other ongoing modeling efforts within the Occoquan watershed. However, the NVRC dataset does not specify forested or open (i.e., pasture) lands; therefore, the NLCD dataset was used to fill in the remaining areas. Dominant land uses in the watershed are forested land (38.3%), agricultural land (32.4%), and developed land (26.5%) which account for a combined 97.2% of the total land area in the watershed.

The potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, residential, and domestic pets waste. Some of these sources are driven by dry weather and others are driven by wet weather. The potential sources of fecal coliform in the watershed were identified and characterized. These sources include permitted point sources, failed septic systems and straight pipes, livestock, wildlife, and pets.

An inventory of the livestock residing in the Bacteria TMDLs for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed was conducted using county-specific data obtained from the United States Department of Agriculture (USDA) National Agricultural Statistics Service, Virginia's Department of Conservation and Recreation, NRCS, Virginia Agricultural Statistics Service (2002),the 2001 Virginia Equine Report, Soil and Water Conservation Districts (SWCD), as well as field surveys.. The data and information indicate the following:

- beef and dairy cattle exist on the pasture areas of the watershed
- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- no feedlots are located in the watershed

Data obtained from the DEQ's Northern Regional Office indicate that there are 15 individually permitted facilities and 67 domestic sewage general permits located in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed. For TMDL development, mean flow values were considered representative of flow conditions at each permitted facility, and were used in the model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

Bacteria Source Tracking

BST was conducted monthly by VA DEQ in 2003-2004 at one station on Kettle Run and at 2 stations on Broad Run. BST was also conducted monthly at 7 stations in 2004-2005 on Broad Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River. Results from both sampling periods indicate that bacteria from human, livestock, wildlife, and pet sources is present in Broad Run, South Run, Popes Head

Creek, the Occoquan River, Little Bull Run, Kettle Run and Bull Run. In the watershed, BST was conducted monthly from July through June. During each sampling season, a total of 12 sampling events were collected at each station.

TMDL Technical Approach

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of delineated watershed under varying scenarios of rainfall and fecal coliform loading. The results from the developed model were used to develop the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

For this TMDL, the river watershed was delineated into 52 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data.

Stream flow data were available from the Occoquan Watershed Monitoring Laboratory (OWML) and utilized in the hydrology calibrations and TMDL development. Weather data were also obtained from OWML. The data used in the model include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation).

The period of January 1996 to December 1999 was used for HSPF hydraulic calibration and January 2000 to December 2003 was used to validate the HSPF model. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the study areas. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Instream water quality data for this station was retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The time period of January 1996 to December 1999 was used for water quality calibration of the model, and the period of January 2000 to December 2003 was used for model validation.

The existing fecal coliform loading was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of January 1995 to December 2004. Virginia has recently changed its bacteria standard from fecal coliform to *E. coli*; therefore, modeled fecal coliform concentrations were changed to *E. coli* concentrations using a translator. Water quality standards for both fecal coliform and *E. coli* were exceeded for the most part during this time period.

TMDL Calculations

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a 30-day geometric mean *E. coli* standard of 126 cfu/100 mL and the instantaneous *E. coli* standard of 235 cfu/100 mL with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1996 to December 2003, fecal coliform loading and instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River. Because Virginia has recently changed its bacteria standard from fecal coliform to *E. coli*, modeled fecal coliform concentrations were translated to *E. coli* concentrations, and the TMDL allocation plan was developed to meet geometric mean and instantaneous *E. coli* standards. Based on the load-allocation scenario analyses, the TMDL allocation plans that will meet the 30-day *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the instantaneous *E. coli* water quality standard of 235 cfu/100 mL are presented in **Table E-1**.

Table E-1: Allocation Plan Loads for E. coli (% reduction) for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River

Watershed	Human Sources (failed septic systems and straight pipes)	Livestock (Direct Instream Loading)	Agricultural and urban non point sources	Wildlife
Broad Run (VAN-A19R-01)	100	100	85	0
Broad Run (VAN-A19R-02)	100	100	90	60
Broad Run (VAN-A19R-05)	100	100	95	80
Kettle Run VAN-A19R-03)	100	100	95	50
South Run (VAN-A19R-04)	100	100	95	50
Popes Head (VAN-A23R-02)	100	100	95	52
Little Bull Run (VAN-A21R-01)	100	100	90	0
Bull Run (VAN-A23R-01)	100	100	90	83
Occoquan River (VAN-A20R-01)	100	100	95	0

The summaries of the bacteria TMDL allocation plan loads for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River are presented in **Table E-2**.

Table E-2: Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River TMDL Allocation Plan Loads for E. coli (cfu/year)

Watershed	WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
Broad Run (VAN-A19R-01)	5.84E+11*	3.99E+11	IMPLICIT	9.84E+11
Broad Run (VAN-A19R-02)	1.36E+11	2.25E+11	IMPLICIT	3.61E+11
Broad Run (VAN-A19R-05)	2.35E+10	1.31E+11	IMPLICIT	1.55E+11
Kettle Run (VAN-A19R-03)	8.30E+12	1.29E+11	IMPLICIT	8.43E+12
South Run (VAN-A19R-04)	4.32E+11	4.83E+10	IMPLICIT	4.80E+11
Popes Head (VAN-A23R-02)	7.12E+11*	1.50E+11	IMPLICIT	8.61E+11
Little Bull Run (VAN-A21R-01)	3.29E+10	2.59E+11	IMPLICIT	2.92E+11
Bull Run (VAN-A23R-01)	1.11E+14*	9.54E+11	IMPLICIT	1.12E+14
Occoquan River (VAN-A20R-01)	2.29E+11*	3.73E+11	IMPLICIT	6.01E+11

(*) includes the MS4 allocations

TMDL Implementation

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-

44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Public Participation

The development of the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River bacteria TMDLs would not have been possible without public participation. Three technical advisory committee (TAC) meetings were held at the DEQ office in Woodbridge, VA on March 1, 2005, November 3, 2005, and March 1, 2006. Three public meetings were also held within the watershed. The first meeting was held at two locations: on March 30, 2005 at the Sully District Governmental Center in Chantilly, Virginia and on April 5, 2005 at the Pennington School in Manassas to discuss the TMDL process and present the impaired segments. The second public meeting was held on December 14, 2005 at the Sully District Governmental Center in Chantilly, Virginia to discuss the preliminary bacteria sources identified for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River. The third public meeting on the development of the bacteria TMDLs for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River Watersheds was held on March 15, 2006 at the

Central Community Library in Manassas, VA to discuss the Draft TMDL. Copies of the presentations were available for public distribution at all meetings and all meetings were public noticed in *The Virginia Register of Regulations.*

Table of Contents

List of Figures

List of Tables

1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a water body can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. DEQ is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. DEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA), passed by the Virginia General Assembly in 1997, and coordinates public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs statewide through the use of federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (DEQ, 2001).

As required by the Clean Water Act and WQMIRA, DEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters. In addition to 303(d) List development, WQMIRA directs DEQ to develop and implement TMDLs for listed waters (DEQ, 2001a). Once TMDLs have been developed, they are distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Segments of Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located the Occoquan River Basin in northern Virginia (Figure 1-1). The watershed is located in the hydrologic unit (HUC) 0270010. The impaired watersheds include portions of Fairfax County, Fauquier County, Loudon County, Prince William County, Fairfax City, Manassas City, and Manassas Park City.

Three segments of Broad Run were identified in VA DEQ's 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The first impaired segment of Broad Run (VAN-A19R-01) is 7.26 miles long and begins at the confluence to Rocky Branch and continues down stream to confluence to Cannon Branch. Four of 19 samples (21.1%) collected at the listing station (ABRU007.58) between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100 mL. The second impaired segment on Broad Run is impaired for 1.51 from the confluence of an unnamed tributary to Broad Run at rivermile 21.43 and continues downstream to the start of Lake Manassas (VAN-A19-R-02). Seven out of 18 samples (38.9%) collected the listing station (1ABRU020.12) between January 1, 1998 and December 31, 2002 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL). The third segment of Broad Run is impaired from the confluence of Mill Run continuing downstream to the confluence of Trapp Run with Broad Run (VAN-A19R-05). Two out of 5 samples collected at station (1ABRU026.40) at the Route 628 Bridge between January 1, 1998 and December 31, 2002 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL).

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The impaired segment of Little Bull Run (VAN-A21-R-01) begins at the confluence of Catharpin Creek to Little Run approximately 0.55 river-miles upstream of Route 704, downstream to its confluence with Lick Branch. Two out of 17 samples (12%) collected between January 1, 1998 and December 31, 2002 at station 1ALII003.97 were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL).

The impaired segment of Bull Run (VAN-A23R-01) begins at the confluence of Cub Run to Bull Run to its confluence with Popes Head Creek. Four out of 34 samples (11.8%) collected between January 1, 1998 and December 31, 2002 were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL) at listing station 1ABUL010.28.

A segment of the Occoquan River is also impaired due to fecal coliform. This segment, VAN-A20R-01, begins downstream from the Lake Jackson impoundment and extends downstream to the confluence of Purcell Branch to the Occoquan River. This segment is currently 1.61 miles but based on a review of the data collected at Prince William Parkway, the total impaired segment will be 5.01 miles in 2006. Between January 1, 1998 and December 31, 2002, four out of 16 samples (25%) were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL) at listing station 1AOCC024.74.

The total length of these nine segments is 37.5 miles (including the addition to the Occoquan River impairment). **Table 1-1** summarizes the details of the impaired segments and **Figure 1-1** presents their location.

Table 1-1: Details of the Bacteria TMDLs for Broad Run, South Run, Kettle Run, Popes Head Creek Little Bull Run, Bull Run and the Occoquan River Bacteria Impairments

Segment ID	Segment Name	Upstream Boundary	Downstream Boundary	Length (Miles)	Years Listed
VAN-A19R-01	Broad Run	Confluence of Rocky Branch	Confluence of Cannon Branch	7.26	2004, 2002
VAN-A19R-02	Broad Run	Confluence of an unnamed tributary	Start of Lake Manassas	1.51	2004, 2002,
VAN-A19R-05	Broad Run	Confluence of Mill Run	Confluence of Trapp Run	1.06	2004
VAN-A19R-04	South Run	Downstream of Lake Brittle	Confluence with Lake Manassas (Bull Run)	2.34	2004
VAN-A19R-03	Kettle Run	Confluence to Kettle Run	Confluence with Broad Run	7.59	2004, 2002
VAN-A23R-02	Popes Head Creek	Confluence of Pine Branch	Confluence with Bull Run	4.92	2004
VAN-A21R-01	Little Bull Run	Confluence of Catharpin Creek	Confluence with Lick Branch	3.03	2004
VAN-A23R-01	Bull Run	Confluence of Cub Run to Bull Run	Confluence of Bull Run with Popes Head Creek	4.80	2004
VAN-A20R-01	Occoquan River	Downstream of Lake Jackson	Confluence of Purcell Branch	5.01*	2004

Note: Portions of these segments also do not support the Aquatic Life and Fish Consumption Uses; TMDLs for these impairments are being developed separately (See Table 1-2)
* Currently the Occoquan River impaired segment is 1.61 miles. Based on a review of the data collected at PW Parkway, the total impaired segment will be 5.01 miles in 2006. For this TMDL, the impairment length of 5.01 will be used in model development.
Source: Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report.

Figure 1-1: Location and Bacteria Impaired Segments of the Broad Run, Kettle Run, South Run, Popes Head Creek Little Bull Run, Bull Run and the Occoquan River Watersheds

Virginia's 2004 305(b)/303(d) Water Quality Assessment Integrated Report identifies two other bacteria impairments in the study watershed in addition to the nine impairments addressed in this report. These additional impairments are summarized in **Table 1-2**. Modeling results from the Cedar Run and Licking Run approved TMDLs will be included in this model development.

Table 1-2: Details of Additional Bacteria Impairments the Occoquan River Watershed Addressed in this Report

Segment ID	Segment Name	Cause(s) of Impairment	Length (Miles)	TMDL Status
A17R	Cedar Run	Bacteria (E.coli)	28.23	Bacteria TMDL Approved 6/17/2004
A17R	Licking Run	Bacteria (E.coli)	6.58	Bacteria TMDL Approved 6/17/2004

Source: Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report.

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a water body and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

1.3.2 Applicable Water Quality Criteria

Effective January 15, 2003, DEQ specified a new bacteria standard in 9 VAC 25-260-170.A, and also revised the disinfection policy in 9 VAC 25-260-170.B. These standards replaced the existing fecal coliform standard and disinfection policy of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

> *"Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples taken over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water. This criterion shall not apply for a sampling station after the [E. coli] bacterial indicators have a minimum of 12 data points or after June 30, 2008, whichever comes first."*

> *"E. coli bacteria shall not exceed a geometric mean of 126 bacteria per 100 mL of water for two or more samples taken during any calendar month nor should it exceed 235 counts per 100 mL of water for a single sample maximum value. No single sample maximum for E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater. Values shown are based on a log standard deviation of 0.4 in freshwater."*

These criteria were adopted because there is a stronger correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

For bacteria TMDL development after January 15, 2003, *E. coli* has become the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, during the transition from fecal coliform to *E. coli* criteria, DCR, DEQ and EPA have agreed to apply a translator to in-stream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting in-stream *E. coli* criteria. The fecal coliform model and in-stream translator are used to calculate *E. coli* TMDLs (DEQ, 2003). The following regression based in-stream translator is used to calculate *E. coli* concentrations from fecal coliform concentrations:

$$E.\ coli\ conc.\ (cfu/100\ mL) = 2^{-0.0172} \times [fecal\ coliform\ conc.\ (cfu/100mL)]^{0.91905}$$

For Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River, TMDLs are required to meet both the geometric mean and instantaneous criteria. The modeled daily fecal coliform concentrations are converted to daily *E. coli* concentrations using the in-stream translator. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

The nine bacteria impaired segments within the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and Occoquan River watersheds are located within the boundaries of Fairfax County, Fauquier County, Loudon County, Prince William County, Fairfax City, Manassas City, and Manassas Park City in Northern Virginia. These segments were initially placed on either the 1998, 2002, or 2004 303(d) lists due to exceedences of the fecal coliform standards for primary contact recreation. The impaired segments comprise a total of approximately 37.5 miles river miles.

One of the first steps in TMDL development is to determine numeric endpoints, or water quality targets, for each impaired segment. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River TMDLs are established in Virginia Water Quality Standards (9 VAC 25-260). These standards state that all waters in Virginia should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore, the current water quality target for these four impairments, as stated in 9 VAC 25-260-170, is an *E. coli* geometric mean no greater than 126 colony-forming units (cfu) per 100 ml for two or more water quality samples taken during any calendar month, and a single sample maximum of 235 cfu per 100 ml at all times.

2.2 Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River. If the TMDLs are developed so that the water quality targets are met under the critical condition, then the targets would also be met under all other conditions.

EPA regulations, 40 CFR 130.7 (c)(1), require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River is protected during times when it is most vulnerable. Critical conditions are important because they describe the combination of factors to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River flow through a continually developing urban setting. The dominant land uses in the basin are forested, agricultural, and developed. Potential sources of fecal coliform include run-off from livestock grazing, manure applications, point source dischargers, and residential waste.

Fecal coliform loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available in-stream water quality data and flow data obtained from Occoquan Watershed Monitoring Laboratory (OWML) flow monitoring stations located on each impaired segment. Flow data were not available at all listing stations but were available near or at the following stations: 1ABUL007.58, 1ABRU020.12, 1ABUL010.28, and 1APOE002.00.

Figure 2-1 depicts fecal coliform concentrations recorded between 1990 and 2004 with the available corresponding stream flow distribution along several impaired segments. Also, **Figure 2-1** includes fecal coliform data from four water quality stations; two stations on Broad Run (1ABUR007.58 and 1ABUR020.12), one station on Bull Run (1ABUL010.28) and one station on Popes Head Creek (1APOE002.00).

Plotting fecal coliform data along with available stream flow data (**Figure 2-1**) revealed that the majority of exceedences tended to occur predominantly during high to moderate flow conditions. This observation applies to data recorded on Bull Run and Popes Head Creek. Several values taken at station 1ABRU020.12 did exceed the water quality standards during dry to low flow conditions.

E. coli and corresponding flow data were only available at DEQ bacteria listing stations 1ABRU020.12, 1ABUL010.28, and 1APOE002.00. The depiction of *E. coli* concentrations versus flows values is similar to the observations made regarding the fecal coliform data. The majority of the exceedances recorded were high during moderate flow conditions (**Figure 2-2**). Similar to **Figure 2-1**, exceedences of the water quality standard at 1ABRU020.12 occurred during moderate to low flow conditions.

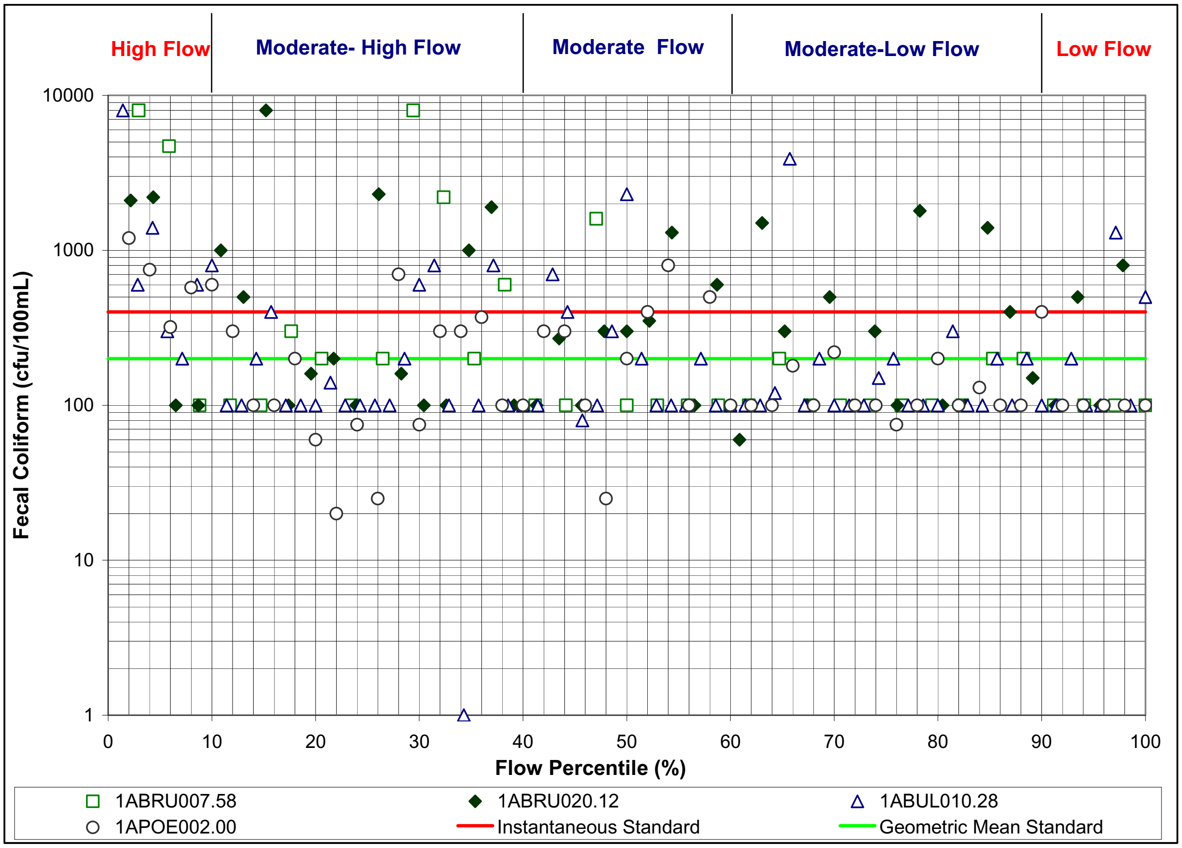

Figure 2-1: Flow Percentile and Fecal Coliform Concentrations

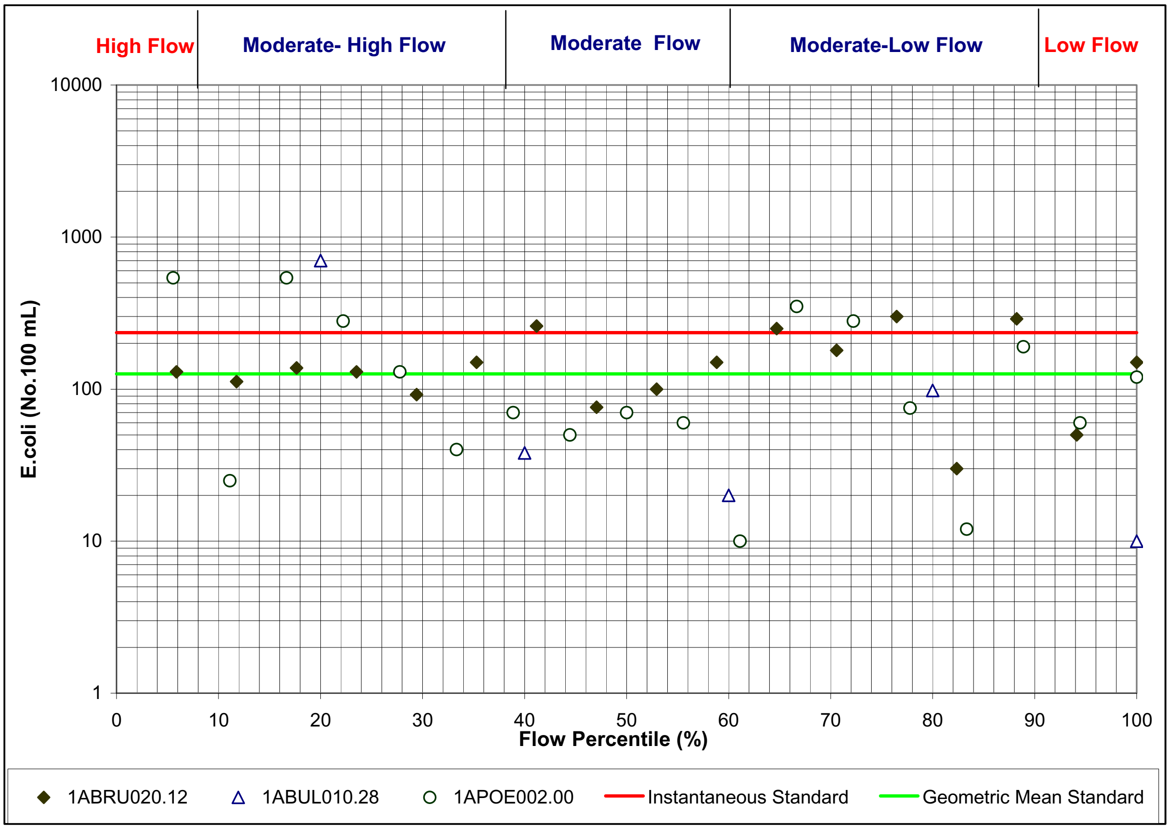

Figure 2-2: Flow Percentile and *E. coli* Concentrations

Consequently, both high and low flow periods were considered as the critical conditions because many of the observed exceedences occurred under these flow volumes. Exceedences under high-flow conditions would occur from indirect sources of bacteria, and would most likely exceed the instantaneous standard. Bacteria loads under low-flow conditions would likely occur from direct sources of bacteria, and would most likely violate the standards.

These TMDLs are required to meet both the geometric mean and instantaneous bacteria standards. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both the instantaneous and geometric mean bacteria standards.

2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

3.0 Watershed Description and Source Assessment

In this section, the types of data available and information collected for the development of the TMDLS for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds are presented. This information was used to characterize each stream and its watershed and to inventory and characterize the potential point and nonpoint sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Physiographic data that describe physical conditions (i.e., topography, soils, and land use) within the watershed

(2) Hydrographic data that describe physical conditions within the stream, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation

(3) Data related to uses of the watershed and other activities in the basin that can be used in the identification of potential fecal coliform sources

(4) Environmental monitoring data that describe stream flow and water quality conditions in the stream

Table 3-1 shows the various data types and the data sources used in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds.

Table 3-1: Inventory of Data and Information Used in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds

Data Category	Description	Source(s)
Watershed physiographic data	Watershed boundary	USGS, DEQ
	Land use/land cover	NLCD, NVRC
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS, NHD, Field surveys
	Stream morphology	
Weather data	Hourly meteorological conditions	NCDC, Earth Info, OWML
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR, local SWCDs, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Local Departments of Health, Utilities, U.S. Census Bureau
	Straight pipes	Census Data, USGS Quad maps
	Best management practices (BMPs)	DCR, NRCS, local SWCDs
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMRs)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient in-stream monitoring data	DEQ, Prince William County, Fairfax County, UOSA
	Stream flow data	USGS, DEQ, OWML

Notes
BASINS: Better Assessment Science Integrating Point and Nonpoint Sources
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Data
NVRC: Northern Virginia Regional Commission
NRCS: Natural Resources Conservation Service
OWML: Occoquan Watershed Monitoring Laboratory
UOSA: Upper Occoquan Sewage Authority
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

The Occoquan watershed is located within the borders of Prince William, Fauquier, Fairfax, Stafford, and Loudoun counties. Within the watershed's boundaries, there are three major urban areas, the cities of Manassas, Manassas Park, and Fairfax City. All impaired streams are located in the Middle Potomac-Anacostia-Occoquan River Basin (USGS Cataloging Unit 02070010). The entire Occoquan watershed is approximately 379,035 acres. Approximately 40 percent of the entire drainage basin is located in Prince William County, 36 percent in Fauquier County and 17 percent in Fairfax County; the remainder of the watershed is divided among the counties of Stafford and Loudoun (less than 1% and 5%, respectively) and the cities of Manassas, Manassas Park, and Fairfax City (2%, less than 1%, and less than 1%, respectively). As shown in **Figure 3-1**, the major highways that run through the watershed are interstate Route 66, U.S. Route 15, and U.S. Route 29. The majority of the major roadways are concentrated in the northeastern section of the watershed in Prince William and Fairfax Counties.

This watershed includes bacteria TMDLs that have already been approved for the bacteria impaired Cedar Run and Licking Run watershed. The results of the approved bacteria TMDLs are incorporated in model development. Therefore, the study area for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River bacteria impairments covers approximately 254,450 acres.

Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River all flow into the Occoquan Reservoir. The impaired segments located on Broad Run are within Prince William County with the upstream section located in Fauquier County and the downstream section located in Manassas City. The impaired segments on Kettle Run, Little Bull Run, and the Occoquan River are also located in Prince William County. The majority of the South Run impaired segment is located in Fauquier County with the downstream section located in Prince William County. The impaired segment located on Bull Run borders both Manassas City and Fairfax County and the Popes Head Creek impaired segment is located within Fairfax County.

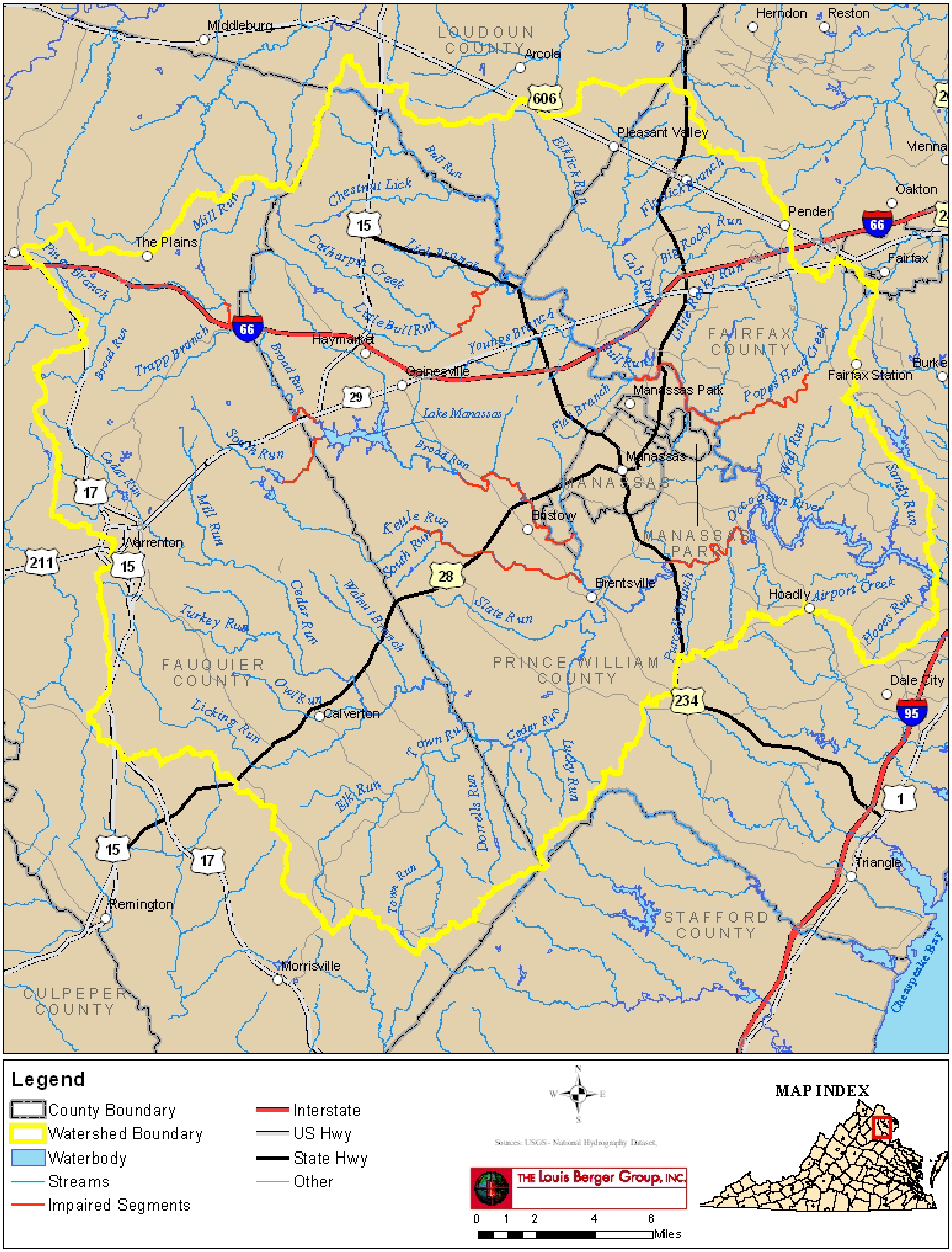

Figure 3-1: Location and Boundary of the Occoquan River Watershed

3.2.1 Topography

A digital elevation model (DEM) based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from the National Map Seamless Data Distribution System maintained by the USGS Eros Data Center. Elevation within the watershed ranges from 80 to 1,368 feet (24 to 417 meters) above mean sea level (**Figure 3-2**).

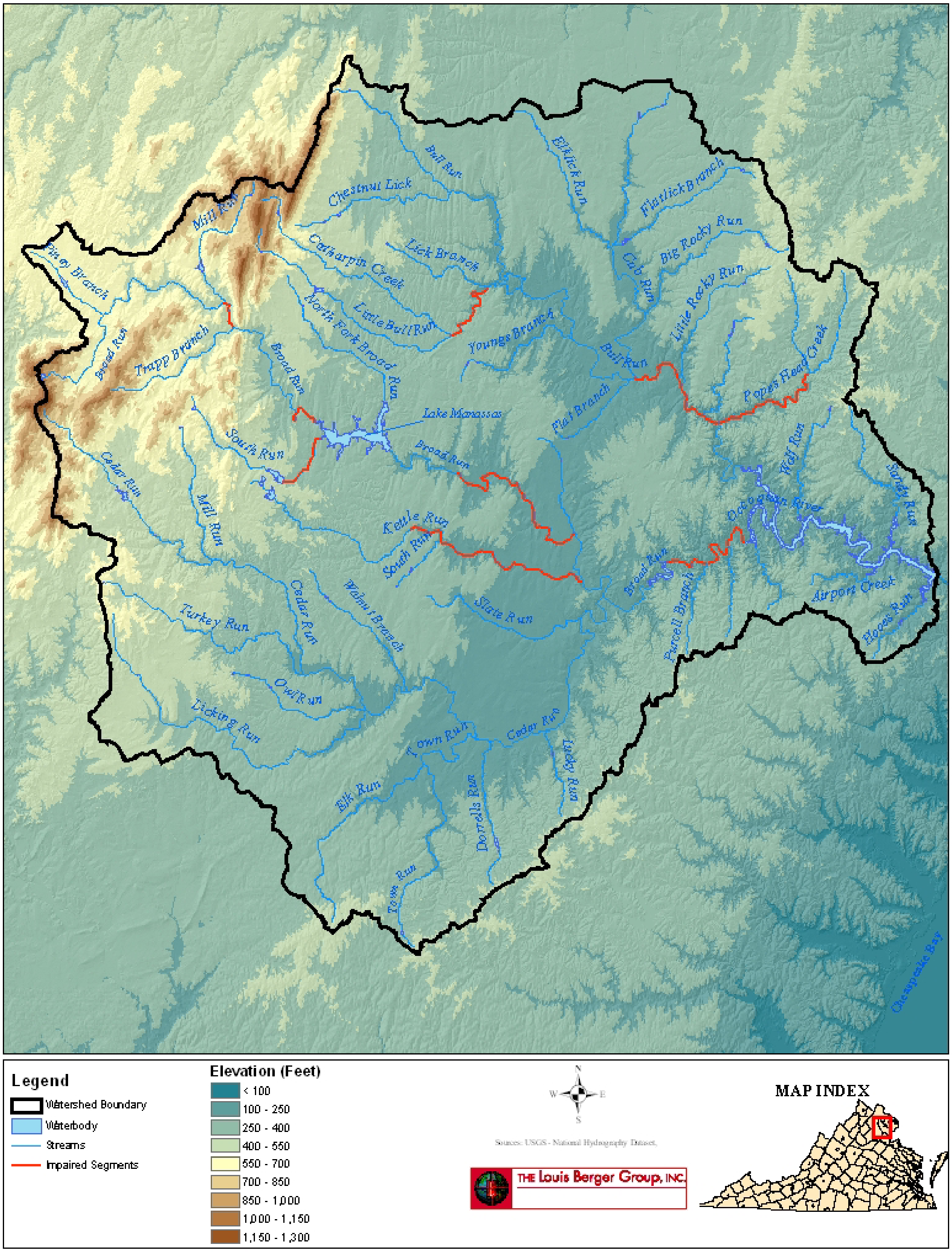

Figure 3-2: Location and Boundary of the Occoquan River Watershed

3.2.2 Soils

The Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed soil characterization was based on data obtained from BASINS, an EPA approved program multi-purpose environmental analysis system that integrates GIS, national watershed data, and environmental assessment and modeling tools. There are twelve general soil associations located in the watershed (see **Table 3-2** and **Figure 3-3**). The four dominant soil types in the watershed are the Penn-Croton-Calverton (VA015), Buckhall-Occoquan-Meadowville (VA013), Jackland-Waxpool-Catlett (VA022) and Catocin-Myersville-Rock Outcrop (VA006) soil associations. Penn-Croton-Calverton soils, which make up the majority of the watershed, consist mostly of moderately deep, well drained soils formed from shale, siltstone, and fine-grained sandstone. The Buckhall-Occoquan-Meadowville soils are very deep, well drained soils with moderate permeability. Jackland-Waxpool-Catlett soils consists of deep, poorly to well drained soils with slow permeability. The Catocin-Myersville-Rock Outcrop soils are moderately deep, well drained soils with moderately rapid permeability. The distribution of soils in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds are presented in **Table 3-2**.

Table 3-2: Soil Types and Characteristics in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River Watersheds

Map Unit ID	Association	Percent Area
VA006	Catoctin-Myersville-Rock Outcrop	10%
VA007	Hayesville-Parker-Peaks	1%
VA010	Codorus-Hatboro-Kinkora	< 1%
VA012	Braddock-Dyke	1%
VA013	Buckhall-Occoquan-Meadowville	15%
VA014	Nason-Manteo-Goldston	< 1%
VA015	Penn-Croton-Calverton	42%
VA021	Airmont-Stumptown-Weverton	2%
VA022	Jackland-Waxpool-Catlett	15%
VA023	Brecknock-Kelly-Croton	7%
VA030	Appling-Wedowee-Louisburg	< 1%
VA071	Manor-Glenelg-Chester	5%
Total		**100%**

The hydrologic soil group linked with each soil association is also presented in **Table 3-3**. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A", soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 3-4**.

Table 3-3: Proportion of Hydrologic Soil Groups within Soil Association

Map Unit ID	Soil Association	Hydrologic Soil Group				
		A	B	C	D	C/D
VA006	Catoctin-Myersville-Rock Outcrop	0	22	69	9	0
VA007	Hayesville-Parker-Peaks	0	91	8	0	0
VA010	Codorus-Hatboro-Kinkora	0	11	61	28	0
VA012	Braddock-Dyke	0	100	0	0	0
VA013	Buckhall-Occoquan-Meadowville	0	97	1	2	0
VA014	Nason-Manteo-Goldston	0	3	80	0	17
VA015	Penn-Croton-Calverton	0	9	81	10	0
VA021	Airmont-Stumptown-Weverton	0	41	59	0	0
VA022	Jackland-Waxpool-Catlett	0	2	9	74	15
VA023	Brecknock-Kelly-Croton	0	45	2	46	7
VA030	Appling-Wedowee-Louisburg	0	90	4	6	0
VA071	Manor-Glenelg-Chester	6	78	13	3	0

Table 3-4: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover
C/D	Combination of Hydrologic Soil Groups C and D

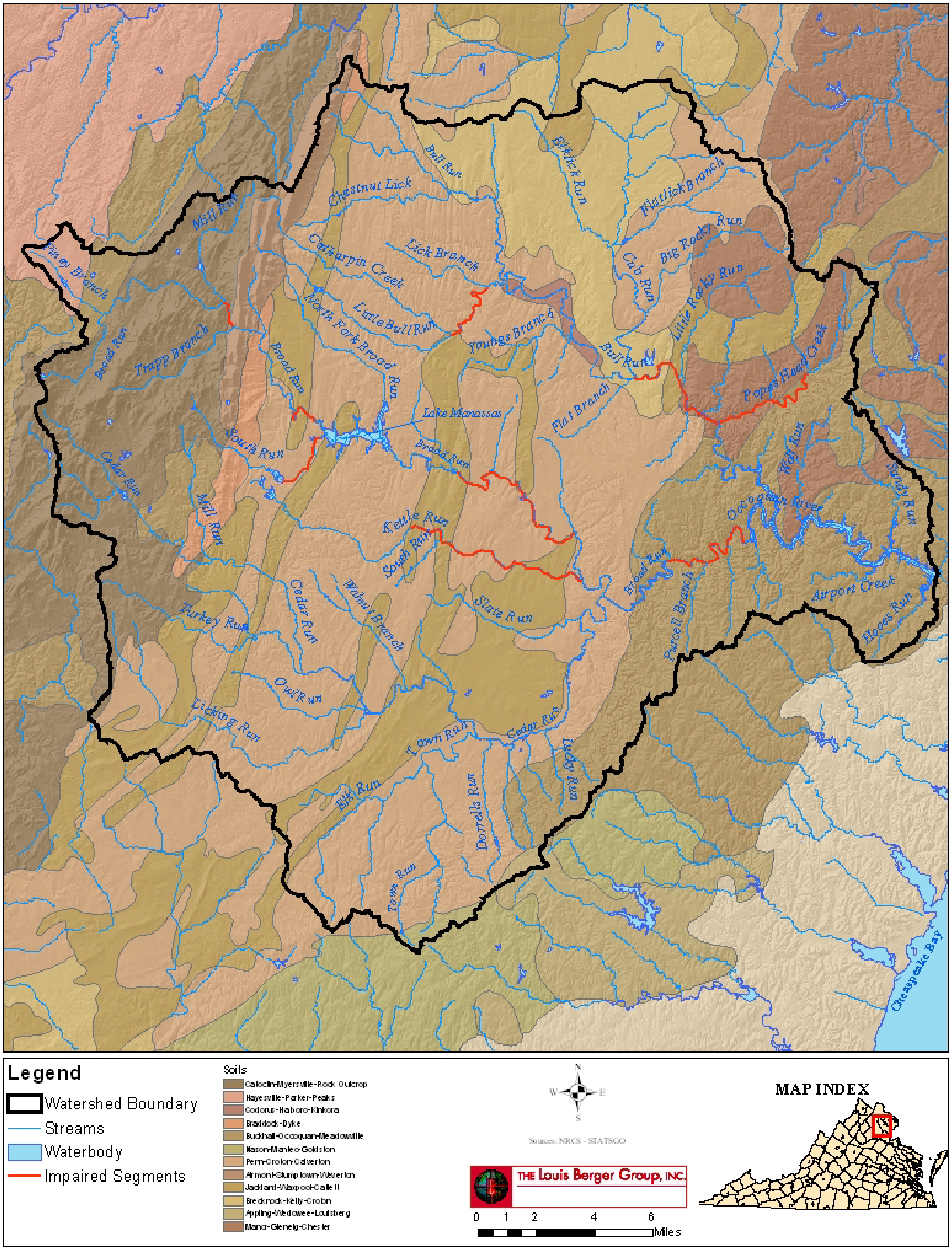

Figure 3-3: Occoquan Watershed Soil Composition

3.2.3 Land Use

The land use characterization for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds watershed was based on land cover data from both the Northern Virginia Regional Commission (NVRC) 2000 Land Use Dataset, and the 1992 USGS National Land Cover Data (NLCD). The NVRC dataset was the most recent available land use dataset, and was also utilized in order to be consistent with other ongoing modeling efforts within the Occoquan watershed. However, the NVRC dataset does not specify forested or open (i.e., pasture) lands; therefore, the NLCD dataset was used to fill in the remaining areas. The distribution of land uses in the watershed, by land area and percentage, is presented in **Table 3-5**. Dominant land uses in the watershed are forested land (38.3%), agricultural land (32.4%), and developed land (26.5%) which account for a combined 97.2% of the total land area in the watershed. Brief descriptions of land use classifications are presented in **Table 3-6**. **Figure 3-4** depicts the land use distribution within the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds.

Table 3-5: Land Use Distribution in the Popes Head Creek, Broad Run, Kettle Run, South Run, Little Bull Run, Bull Run and the Occoquan River Watershed

General Land Use Category	Specific Land Use Category	Acres	Percent of Watershed	Total Percent
Water/Wetlands	Open Water	2,348	0.90%	1.10%
	Wetlands	1,402	0.60%	
Developed	Low Intensity Residential	43,819	17.20%	26.50%
	Medium/High Intensity Residential	24,633	9.70%	
	Commercial/Industrial	16,000	6.30%	
	Institutional	3,792	1.50%	
Agriculture	Pasture/Hay/Livestock	45,370	17.80%	32.40%
	Row Crop	18,618	7.30%	
Forest	Deciduous Forest	67,361	26.50%	38.30%
	Evergreen Forest	12,546	4.90%	
	Mixed Forest	13,060	5.10%	
Other	Quarries/Strip Mines/Gravel Pits	87	< 1.0%	1.70%
	Transitional	1,430	0.60%	
	Urban/Recreational Grasses	3,984	1.60%	
Total		**254,450**	**100%**	**100%**

Table 3-6 Descriptions of Land Use Types	
Land Use Type	**Description**
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/ Industrial/ Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: Multi-Resolution Land Characteristics Consortium NLCD

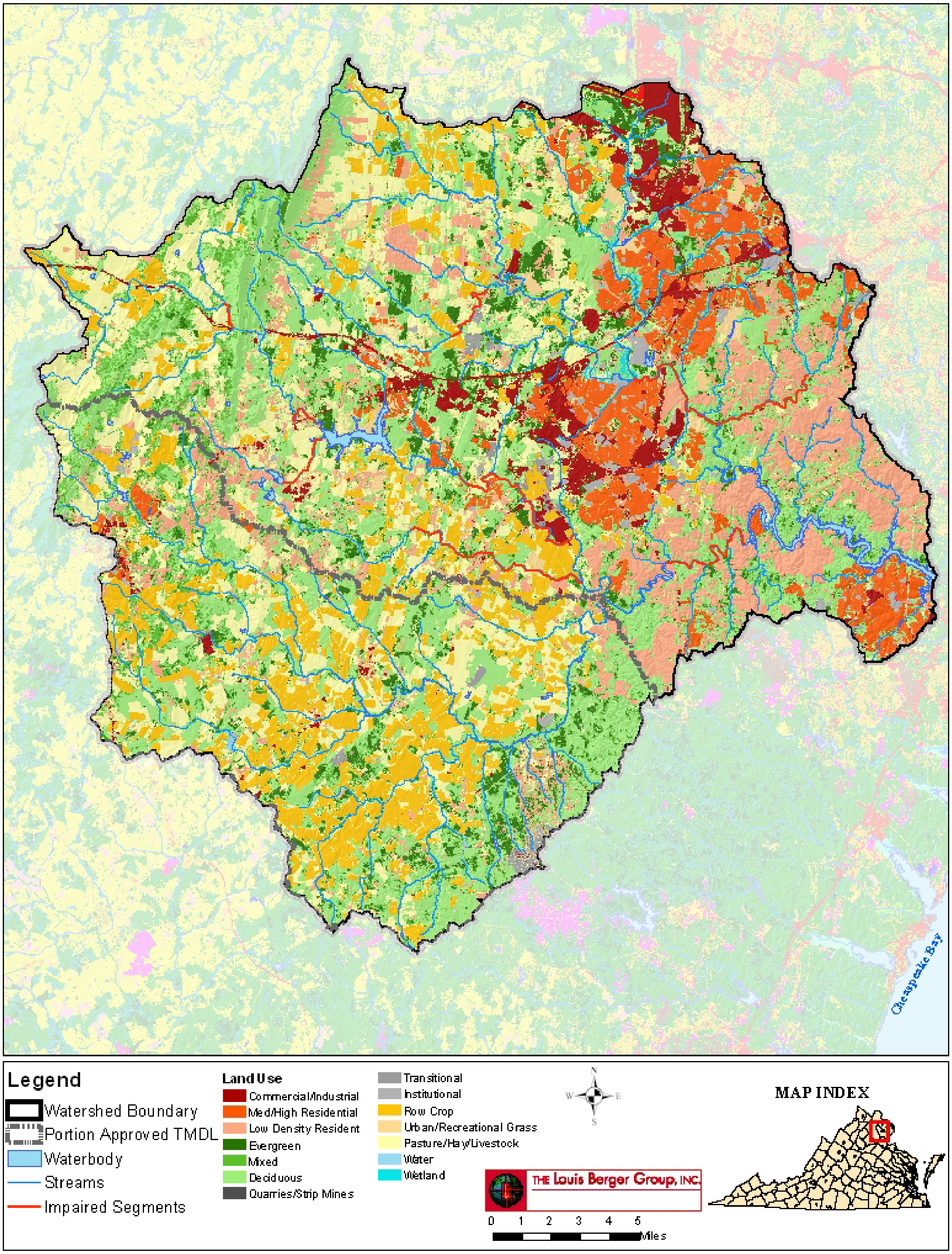

Figure 3-4: Land Use in the Broad Run, Kettle Run, South Run, Popes Head Creek Little Bull Run, Bull Run and the Occoquan River Watersheds

3.3 Stream Flow Data

Stream flow data for the Popes Head Creek, Broad Run, Kettle Run, South Run, Little Bull Run, Bull Run and the Occoquan River watershed were not available from USGS stream flow-gauging stations since stations located in the watershed stopped recording stream flow before 1995. Flow data was obtained from the Occoquan Watershed Monitoring Laboratory (OWML). The Occoquan Watershed Monitoring Laboratory (OWML), which is operated by the Virginia Polytechnic Institute Department of Civil Engineering and was established by mandate of the Occoquan Policy, has conducted water quality monitoring efforts since 1972. The period of record and number of records of stream flow are presented in **Table 3-7**. The location of these flow-gauging stations is presented in **Figure 3-5**. Stream flow data obtained from OWML stations were used in the set-up, hydrological calibration, and validation of the model.

Table 3-7: OWML Flow Gauging Stations in the Road Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed

Station ID	Station Name	Period of Record	Number of Records
ST30	Broad Run near Bristow	1994-2004	4018
ST40	Bull Run at Yeats Ford	1994-2004	4018
ST45	Bull Run at Yorkshire	1994-2004	4018
ST50	Cub Run near Bull Run	1994-2004	4018
ST60	Bull Run near Catharpin	1994-2004	4018
ST70	Broad Run at Buckland	1994-2004	4018

Figure 3-5: Flow Monitoring Stations in the Road Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

3.4 DEQ Ambient Water Quality Data

Water quality data for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds were obtained from DEQ, which conducted sampling at 75 water quality monitoring stations located within the watershed. Locations of these stations are summarized in **Table 3-8.** **Figure 3-6** depicts the locations of these monitoring stations.

Table 3-8: DEQ Water Quality Monitoring Stations Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and Occoquan River Watersheds

No.	Water Body ID	Station ID	Station Description	Stream Name
1	A22R	1ABIR000.76	Rt. # 29/211 Bridge	Big Rocky Run
2	A22R	1ABIR005.21	Rt. # 645	Big Rocky Run
3	A19R	1ABRU001.59	Rt. # 692, Lucasville Rd	Broad Run
4	A19R	1ABRU006.65	At Southern RR Bridge off Rt. 28	Broad Run
5	A19R	1ABRU007.58	Rt. # 28	Broad Run
6	A19R	1ABRU011.24	Sudley Manor Drive	Broad Run
7	A19R	1ABRU015.77	Rt. # 675, below Lake Manassas Dam	Broad Run
8	A19L	1ABRU016.28	Lake Manassas Station #1 100 Yds Above Spillway	Broad Run
9	A19L	1ABRU017.58	Lake Manassas Station #2 Mid-Lake	Broad Run
10	A19L	1ABRU018.78	Lake Manassas Station #3 Upper Lake	Broad Run
11	A19R	1ABRU020.12	Rt. # 29/15	Broad Run
12	A19R	1ABRU026.40	Rt. # 628, Bust Head Rd	Broad Run
13	A19R	1ABRU029.80	Rt. # 55	Broad Run
14	A24R	1ABUL001.57	Rt. # 612	Bull Run
15	A23R	1ABUL009.61	Downstream from Rt. # 28	Bull Run
16	A23R	1ABUL010.28	Rt. # 28	Bull Run
17	A23R	1ABUL011.03	Rt. # 616, Old Centreville Rd.	Bull Run
18	A21R	1ABUL016.31	Rt. # 29/211	Bull Run
19	A21R	1ABUL025.94	Rt. # 705	Bull Run
20	A21R	1ACAA000.83	Cartharpin Cr. 0.35 RM below Rt.# 676	Catharpin Creek
21	A21R	1ACAA003.46	Rt. # 676	Catharpin Creek
22	A21R	1ACAA008.01	Rt. # 600	Catharpin Creek
23	A18R	1ACER000.20	Rt. # 619 Bridge	Cedar Run
24	A22R	1ACUB002.61	Rt. # 658, Compton Rd	Cub Run
25	A22R	1ACUB003.74	Rt. # 29/211 Bridge	Cub Run

Table 3-8: DEQ Water Quality Monitoring Stations Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and Occoquan River Watersheds

No.	Water Body ID	Station ID	Station Description	Stream Name
26	A22R	1ACUB008.60	Rt. # 661, Old Lee Highway	Cub Run
27	A22R	1ACUB011.25	Rt. # 50	Cub Run
28	A22R	1AELC001.39	Rt. # 609 (Pleasant Valley Rd)	Elklick Run
29	A21R	1AFLB000.64	Rt. # 1501 Bridge	Flat Branch
30	A21R	1AFLB001.40	Rt. # 1530 Bridge	Flat Branch
31	A21R	1AFLB002.53	Rt. # 234	Flat Branch
32	A22R	1AFLL000.62	Between Rt. # 609 and Rt. # 620	Flatlick Branch
33	A22R	1AFLL000.88	Rt. # 620	Flatlick Branch
34	A22R	1AFLL001.98	Rt. # 28	Flatlick Branch
35	A22R	1AFLL002.76	Rt. # 657	Flatlick Branch
36	A22R	1AFLL004.37	Rt. # 645	Flatlick Branch
37	A24R	1AHOO000.34	Rt. # 641 (Old Bridge Rd)	Hooes Run
38	A23R	1AJOH002.42	Rt. # 658	Johnny Moore Creek
39	A23R	1AJOH004.08	Rt. # 3546	Johnny Moore Creek
40	A23R	1AJOH005.04	Rt. # 645	Johnny Moore Creek
41	A19R	1AKET000.80	Rt. # 619 (Bristow Rd)	Kettle Run
42	A19R	1AKET002.06	Rt.# 611	Kettle Run
43	A19R	1AKET007.80	Rt. # 708	Kettle Run
44	A19R	1AKET011.03	Downstream of Rt.# 603	Kettle Run
45	A19R	1AKET011.94	Rt. # 603	Kettle Run
46	A19R	1AKET012.03	Rt. # 761	Kettle Run
47	A21R	1ALII000.14	Rt. # 234	Little Bull Run
48	A21R	1ALII003.97	Rt. # 705 Bridge	Little Bull Run
49	A21R	1ALII006.75	Rt. # 676	Little Bull Run
50	A17R	1ALIP001.00	Rt. # 658 (Compton Rd.)	Little Rocky Run
51	A18R	1ANOF002.14	Rt. # 29/211 Bridge	North Fork Broad Run
52	A24R	1AOCC008.11	Under powerline at dam	Occoquan River
53	A24R	1AOCC008.80	Under powerline	Occoquan River
54	A24R	1AOCC011.88	At Jacob's Rock	Occoquan River
55	A24R	1AOCC014.34	Above Ryan's Dam	Occoquan River
56	A19R	1AOCC019.36	Rt. # 663 Bridge	Occoquan River
57	A20R	1AOCC021.35	Rt. # 3000 (Prince William PKWY)	Occoquan River
58	A20R	1AOCC024.74	Rt. # 234 Bridge	Occoquan River

Table 3-8: DEQ Water Quality Monitoring Stations Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and Occoquan River Watersheds				
No.	**Water Body ID**	**Station ID**	**Station Description**	**Stream Name**
59	A23R	1APIY000.05	Rt. # 660	Peyton Run
60	A23R	1APIY002.72	Rt. # 620	Peyton Run
61	A20R	1APOE001.55	Rt. # 659	Popes Head Creek
62	A23R	1APOE002.00	Rt. # 645 (Clifton Rd.)	Popes Head Creek
63	A23R	1APOE005.40	Rt. # 660	Popes Head Creek
64	A23R	1APOE007.20	Rt. # 654	Popes Head Creek
65	A23R	1APOE008.36	Rt. # 620	Popes Head Creek
66	A23R	1APUR001.20	Rt. # 643	Purcell Branch
67	A24R	1ASAD001.76	Cathedral Forest Drive	Sandy Run
68	A24R	1ASAD003.40	Rt. # 643	Sandy Run
69	A18R	1ASOT001.44	Rt. # 215 Bridge	South Run
70	A19R	1ASOT001.65	Rt. # 652	South Run
71	A19R	1ATRA000.09	Rt. # 55	Trapp Branch
72	A19R	1ATRA001.02	Rt. # 674	Trapp Branch
73	A24R	1AWOL001.26	Rt. # 643	Wolf Run
74	A17R	1AXAC000.09	Rt. # 1501	Tributary to Long Branch
75	A21R	1AXGB000.07	Rt. # 1530	Tributary to Flat Branch

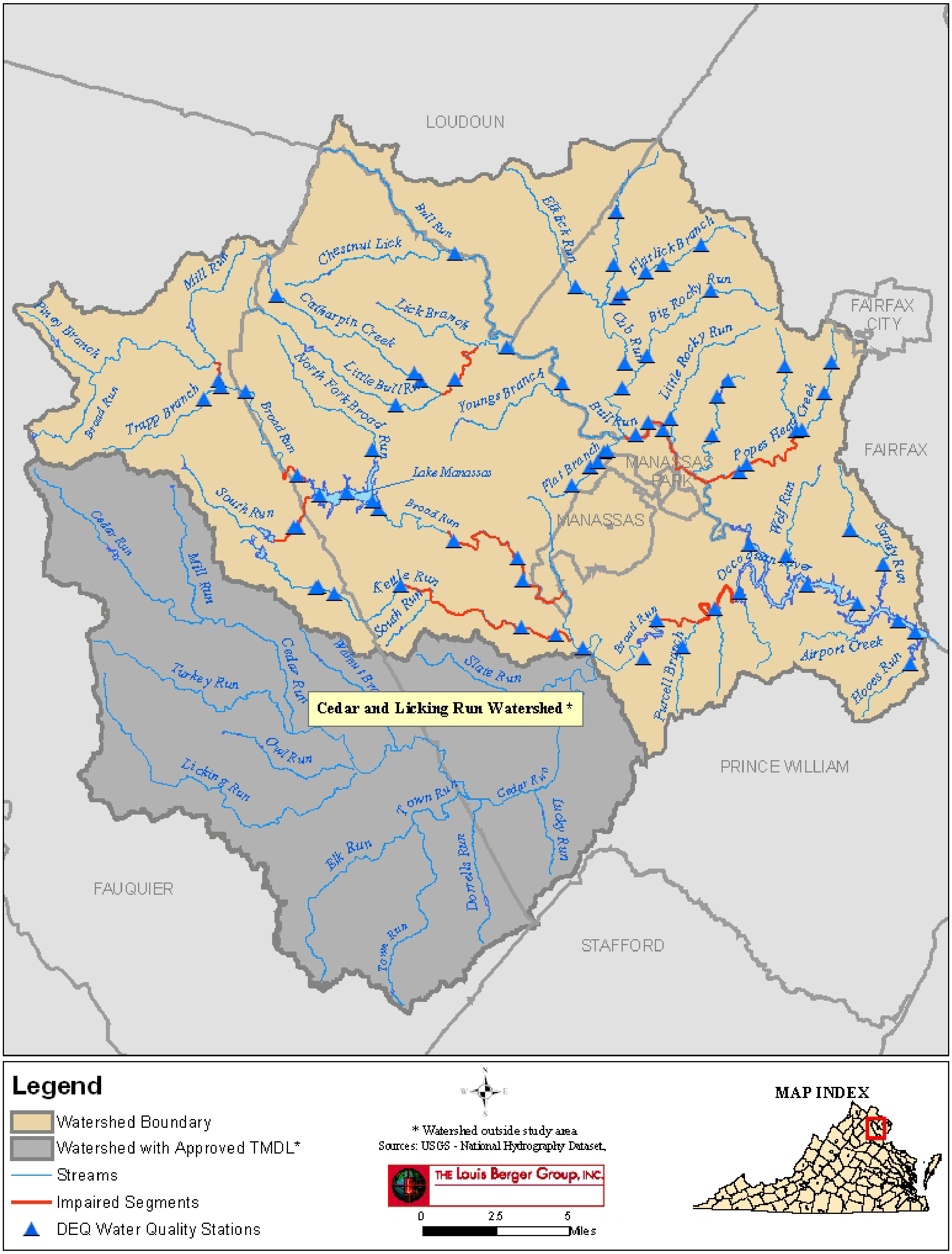

Figure 3-6: Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed DEQ Water Quality Monitoring Stations

Out of the 75 water quality stations in located in the watershed, 34 stations were sampled between 1990 and 2005 for fecal coliform bacteria. **Table 3-9** lists the water quality sampling period of record, the number of samples, the minimum, maximum and average concentrations observed, and the number and percentage of samples violating the water quality standards collected between 1990 and 2005. The stations formatted in bold text are the DEQ listing stations for the bacteria impaired segments. Water quality data collected from the Popes Head Creek, Kettle Run, South Run, Broad Run, Little Bull Run, Bull Run, and the Occoquan River stations indicated that exceedences of the fecal coliform standard ranged between 0 to 67 percent for the instantaneous maximum criterion of 400 cfu/100 ml and from 0 to 5 percent for the geometric mean criterion of 200 cfu/100 ml.

Table 3-9: Summary of DEQ Fecal Coliform Bacteria Sampling Events in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds between 1990 and 2005

No.	Station ID	Sample Date		No. of Samples	Min (cfu/ 100mL)	Max (cfu/ 100mL)	Avg (cfu/ 100mL)	Exceedances			
								Inst. Max[1]		Geo. Mean[2]	
		First	Last					No	%	No.	%
1	1ABRU001.59	8/27/2001	12/12/2005	30	25	4100	439	6	20%	-	-
2	**1ABRU007.58**	**8/7/1991**	**6/21/2001**	**41**	**18**	**8000**	**839**	**7**	**17%**	**-**	**-**
3	1ABRU011.24	2/11/2003	4/6/2004	14	30	4000	791	3	21%	-	-
4	1ABRU015.77	8/27/2001	10/24/2001	2	100	200	150	0	0%	-	-
5	1ABRU016.28	7/17/1997	7/17/1997	1	100	100	100	0	0%	-	-
6	1ABRU017.58	9/17/1992	7/17/1997	2	100	100	100	0	0%	-	-
7	1ABRU018.78	9/17/1992	7/17/1997	2	100	100	100	0	0%	-	-
8	**1ABRU020.12**	**5/8/1991**	**7/12/2004**	**75**	**18**	**16000**	**846**	**23**	**31%**	**-**	**-**
9	**1ABRU026.40**	**8/27/2001**	**7/27/2005**	**17**	**1**	**7700**	**724**	**5**	**29%**	**-**	**-**
10	1ABRU029.80	7/30/2003	7/12/2004	11	50	900	332	2	18%	-	-
11	1ABUL009.61	4/20/2005	4/20/2005	1	25	25	25	0	0%	-	-
12	**1ABUL010.28**	**5/8/1991**	**7/27/2005**	**100**	**1**	**8000**	**502**	**19**	**19%**	**-**	**-**
13	1ABUL011.03	9/7/1999	9/7/1999	1	100	100	100	0	0%	-	-
14	1ABUL025.94	4/17/1991	12/12/2005	59	18	700	150	5	8%	-	-
15	1ACAA000.83	4/23/2003	4/23/2003	1	50	50	50	0	0%	-	-
16	1ACAA003.46	8/2/1994	8/2/1994	1	400	400	400	0	0%	-	-
17	1ACAA008.01	8/2/1994	8/2/1994	1	100	100	100	0	0%	-	-
18	1ACUB002.61	8/23/2001	12/12/2005	25	25	2000	386	7	28%	-	-
19	1ACUB003.74	4/17/1991	5/16/2001	41	100	2100	420	12	29%	-	-
20	1ACUB008.60	8/23/2001	6/23/2003	9	100	8000	1000	1	11%	-	-
21	1AELC001.39	8/23/2001	4/5/2005	13	25	2000	275	2	15%	-	-

Table 3-9: Summary of DEQ Fecal Coliform Bacteria Sampling Events in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds between 1990 and 2005

No.	Station ID	Sample Date		No. of Samples	Min (cfu/ 100mL)	Max (cfu/ 100mL)	Avg (cfu/ 100mL)	Exceedances			
								Inst. Max[1]		Geo. Mean[2]	
		First	Last					No	%	No.	%
22	1AFLL000.62	10/22/2001	10/22/2001	1	100	100	100	0	0%	-	-
23	**1AKET000.80**	**8/7/1991**	**10/24/2001**	**36**	**18**	**8000**	**1522**	**13**	**36%**	**-**	**-**
24	1AKET002.06	2/20/2002	7/12/2004	22	25	2900	490	6	27%	1	5%
25	1AKET011.03	5/13/2002	5/13/2002	1	100	100	100	0	0%	-	-
26	1AKET012.03	7/30/2003	7/12/2004	12	50	2600	413	3	25%	-	-
27	**1ALII003.97**	**4/17/1991**	**7/27/2005**	**51**	**10**	**4900**	**425**	**11**	**22%**	**-**	**-**
28	1AOCC021.35	10/15/2002	12/5/2005	22	1	1545	236	3	14%	-	-
29	**1AOCC024.74**	**4/17/1991**	**5/16/2001**	**37**	**18**	**3500**	**451**	**8**	**22%**	**-**	**-**
30	**1APOE002.00**	**4/17/1991**	**7/27/2005**	**65**	**20**	**1200**	**228**	**10**	**15%**	**0**	**0%**
31	1ASAD003.40	12/20/2001	6/27/2002	5	50	650	200	1	20%	-	-
32	**1ASOT001.44**	**5/8/1991**	**6/21/2001**	**56**	**100**	**1700**	**325**	**11**	**20%**	**-**	**-**
33	1ATRA001.02	7/30/2003	6/17/2004	24	50	3900	1075	16	67%	-	-
34	1AWOL001.26	2/11/2003	12/5/2005	18	25	2000	384	5	28%	-	-

[1] Instantaneous maximum fecal coliform bacteria concentration of 400 cfu/100 ml.
[2] Geometric mean fecal coliform bacteria concentration of 200 cfu/100 ml, calculated only when two or more samples are collected within a calendar month.
Note: Rows in **bold** are listing stations for the bacteria impairment segments.

Twenty-eight stations within the watershed were sampled between 1990 and 2005 for *E.coli* bacteria. **Table 3-10** lists the water quality sampling period of record, the number of samples, the minimum, maximum and average concentrations observed, and the number and percentage of samples violating the water quality standards collected between 1990 and 2005. The stations formatted in bold text are the DEQ listing stations for bacteria. *E.coli* exceedences of the instantaneous maximum ranged between 0 and 100 percent and between 0 and 19 percent for the geometric mean.

Table 3-10: Summary of DEQ E. coli Bacteria Sampling Events in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds between 1990 and 2005

								Exceedances			
		Sample Date		No. of	Min (cfu/ 100mL)	Max (cfu/ 100mL)	Avg (cfu/ 100mL)	Inst. Max[1]		Geo. Mean[2]	
No.	Station ID	First	Last	Samples				No	%	No.	%
1	1ABRU001.59	10/15/2002	12/12/2005	25	10	720	156	9	36%	-	-
2	1ABRU011.24	7/30/2003	6/17/2004	16	6	1400	264	6	38%	3	19%
3	**1ABRU020.12**	**5/20/2002**	**7/12/2004**	**17**	**30**	**300**	**152**	**6**	**35%**	**1**	**6%**
4	**1ABRU026.40**	**7/22/2004**	**7/27/2005**	**12**	**36**	**2700**	**420**	**12**	**100%**	**-**	**-**
5	1ABRU029.80	7/30/2003	7/12/2004	11	50	800	245	5	45%	-	-
6	1ABUL009.61	4/20/2005	4/20/2005	1	10	10	10	1	100%	-	-
7	**1ABUL010.28**	**7/22/2004**	**7/27/2005**	**12**	**10**	**700**	**108**	**12**	**100%**	**0**	**0%**
8	1ABUL016.31	7/12/2005	9/14/2005	2	50	180	115	2	100%	0	0%
9	1ABUL025.94	5/20/2002	12/12/2005	17	10	380	101	8	47%	-	-
10	1ACAA000.83	4/23/2003	4/23/2003	1	30	30	30	0	0%	-	-
11	1ACAA003.46	7/12/2005	11/15/2005	3	25	380	218	3	100%	-	-
12	1ACUB002.61	5/30/2002	12/12/2005	20	25	800	169	10	50%	-	-
13	1AELC001.39	7/27/2004	4/5/2005	5	25	2000	647	5	100%	-	-
14	1AHOO000.34	8/11/2005	12/1/2005	3	120	1600	640	3	100%	-	-
15	**1AKET000.80**	**4/19/2001**	**10/24/2001**	**3**	**30**	**340**	**197**	**1**	**33%**	**-**	**-**
16	1AKET002.06	5/30/2002	7/12/2004	18	18	730	211	7	39%	2	11%
17	1AKET012.03	7/30/2003	7/12/2004	12	50	550	179	4	33%	-	-
18	**1ALII003.97**	**7/22/2004**	**7/27/2005**	**11**	**10**	**261**	**82**	**11**	**100%**	**-**	**-**
19	1ALII006.75	7/12/2005	11/15/2005	3	25	200	83	3	100%	-	-
20	1ALIP001.00	8/7/2003	8/3/2004	5	25	1000	286	1	20%	-	-
21	1AOCC021.35	10/15/2002	12/5/2005	21	1	580	129	14	67%	-	-
22	**1APOE002.00**	**5/30/2002**	**7/27/2005**	**26**	**10**	**540**	**124**	**18**	**69%**	**0**	**0%**
23	1APUR001.20	8/7/2003	8/3/2004	5	25	880	330	3	60%	-	-
24	1ASAD001.76	8/11/2005	11/8/2005	3	25	2000	683	3	100%	-	-
25	1ASAD003.40	5/30/2002	6/27/2002	2	30	450	240	2	100%	-	-
26	1ASLE000.36	7/12/2005	11/15/2005	2	100	120	110	2	100%	-	-
27	1ATRA001.02	7/30/2003	6/17/2004	24	50	1800	671	20	83%	-	-
28	1AWOL001.26	2/11/2003	12/5/2005	18	10	2000	281	18	100%	-	-

[1] Instantaneous maximum *E.coli* bacteria concentration of 235/100 ml

[2] Geometric mean fecal *E.coli* bacteria concentration of 126/100 ml, of water for two or more samples taken during any calendar month

Note: Rows in **bold** are listing stations for the bacteria impairment segments.

3.4.1 DEQ Bacteria Source Data

As part of the TMDL development, Bacteria Source Tracking (BST) sampling was conducted at 10 locations throughout the watershed. The objective of the BST study was to identify the sources of fecal coliform in the listed segments of Popes Head Creek, Broad Run, Kettle Run, South Run, Broad Run, Little Bull Run, Bull Run and the Occoquan River. After identifying these sources, this information was used in the model set-up, and in the distribution of fecal coliform loadings among the various sources.

There are various methodologies used to perform BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are referred to as "DNA fingerprinting," and are based on the unique genetic makeup of different strains, or subspecies, of fecal coliform bacteria. Biochemical (phenotype) methods are based on detecting biochemical substances produced by bacteria. The type and quantity of these substances are measured to identify the bacteria source. Chemical methods are based on testing for chemical compounds that are associated with human wastewaters, and are restricted to determining if sources of pollution are human or non-human.

For the Popes Head Creek, Broad Run, Kettle Run, South Run, Little Bull Run, Bull Run and the Occoquan River TMDLs, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically, 48 isolates per unknown source such as an in-stream water quality sample.

BST was conducted monthly in 2003-2004 at one station on Kettle Run and at 2 stations on Broad Run. BST was also conducted monthly at 7 stations in 2004-2005 on Broad Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River. Results from both sampling periods indicate that bacteria from human, livestock, wildlife, and pet sources is present in Broad Run, South Run, Popes Head Creek, the Occoquan River, Little Bull Run, Kettle Run and Bull Run. In the watershed, BST was conducted monthly from July through June. During each sampling season, a total of 12 sampling events were collected at each station. The location of each BST station is presented in **Table 3-11**. **Figure 3-7** depicts the locations of the monitoring stations in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed.

Table 3-11: BST Monitoring Stations Located in the Popes Head Creek, Kettle Run, South Run, Broad Run, Little Bull Run, Bull Run and the Occoquan River Watersheds

No.	Watershed Code	Station ID	Station Description	Stream Name
1	A19R	1ABRU011.24	Sudley Manor Drive	Broad Run
2	A19R	1ABRU020.12	Rt. # 29/15	Broad Run
3	A19R	1ABRU026.40	Rt. # 628, Bust Head Rd	Broad Run
4	A23R	1ABUL010.28	Rt. # 28	Bull Run
5	A19R	1AKET002.06	Rt.# 611	Kettle Run
6	A21R	1ALII003.97	Rt. # 705 Bridge	Little Bull Run
7	A20R	1AOCC021.35	Rt. # 3000 (Prince William PKWY)	Occoquan River
8	A23R	1APOE002.00	Rt. # 645 (Clifton Rd.)	Popes Head Creek
9	A19R	1ASOT001.65	Rt. # 652	South Run

Four categories of fecal bacteria sources were considered: wildlife, human, livestock and pet. Results from all 12 sampling events at each station, are presented in **Table 3-12** and results are depicted in **Figures 3-8** through **3-16**. *E.coli* concentrations exceeded the instantaneous maximum *E.coli* bacteria criterion of 235 cfu/100mL 25 times in the 144 samples collected at all 9 stations. In terms of percentages, the instantaneous *E.coli* standard was violated anywhere from 0 percent of the time station 1APOE002.00 to 25 percent of the time at stations 1ABRU026.40, 1ABRU020.12, and 1AKET002.06. Figures 3-6 through 3-12 depict the BST source distributions at all stations.

Figure 3-7: Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds Bacteria Source Tracking Sampling Stations

Table 3-12: Results of BST Analysis Conducted in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed							
VADEQ	Date of Sample	Number of Isolates	E. coli (cfu/ 100ml)	Wildlife	Human	Livestock	Pet
1AKET002.06 3 out of 12 samples (25%) exceed 235 cfu/100ml	7/30/2003	24	730	38%	0%	8%	54%
	8/5/2003	24	140	67%	4%	12%	17%
	9/2/2003	24	300	42%	0%	12%	46%
	10/1/2003	24	78	12%	0%	55%	33%
	11/3/2003	24	240	17%	0%	83%	0%
	12/2/2003	24	168	42%	0%	25%	33%
	2/10/2004	24	148	67%	4%	12%	17%
	3/25/2004	23	18	13%	17%	0%	70%
	4/6/2004	24	128	50%	4%	21%	25%
	5/10/2004	12	50	58%	0%	0%	42%
	6/17/2004	12	120	58%	0%	42%	0%
	7/12/2004	11	100	45%	0%	10%	45%
1ABRU011.24 2 out of 12 samples (17%) exceed 235 cfu/100ml	7/30/2003	24	1400	62%	0%	38%	0%
	8/5/2003	24	220	67%	0%	33%	0%
	9/2/2003	24	620	38%	4%	0%	58%
	10/1/2003	24	108	66%	0%	17%	17%
	11/3/2003	24	152	12%	0%	84%	4%
	12/2/2003	24	64	46%	0%	0%	54%
	1/20/2004	10	20	60%	0%	10%	30%
	2/10/2004	24	130	59%	4%	25%	12%
	3/25/2004	5	6	40%	20%	20%	20%
	4/6/2004	24	66	71%	8%	17%	4%
	5/10/2004	8	40	25%	0%	0%	75%
	6/17/2004	22	230	95%	0%	5%	0%
1ABRU020.12 3 out of 12 samples (25%) exceed 235 cfu/100ml	7/30/2003	24	290	67%	0%	25%	8%
	8/5/2003	24	220	54%	0%	46%	0%
	9/2/2003	24	150	25%	0%	12%	63%
	10/1/2003	24	76	50%	0%	29%	21%
	11/3/2003	24	92	59%	4%	25%	12%
	12/2/2003	24	112	0%	0%	33%	67%
	2/10/2004	24	130	84%	0%	12%	4%
	3/25/2004	16	30	25%	12%	63%	0%
	4/6/2004	24	138	12%	12%	25%	51%
	5/10/2004	24	250	17%	0%	71%	12%
	6/17/2004	24	180	58%	0%	38%	4%
	7/12/2004	24	260	33%	0%	59%	8%
1ABRU026.40 3 out of 12 samples (25%)	7/22/2004	24	640	67%	0%	12%	21%
	8/12/2004	24	800	25%	12%	51%	12%
	9/8/2004	24	2,700	54%	0%	8%	38%

Table 3-12: Results of BST Analysis Conducted in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

VADEQ	Date of Sample	Number of Isolates	E. coli (cfu/ 100ml)	Wildlife	Human	Livestock	Pet
exceed 235 cfu/100ml	10/27/2004	24	98	38%	29%	29%	4%
	12/14/2004	24	74	33%	25%	25%	17%
	1/26/2005	24	72	8%	8%	33%	51%
	2/10/2005	24	118	4%	38%	12%	46%
	3/16/2005	22	40	14%	58%	14%	14%
	4/27/2005	16	36	25%	12%	57%	6%
	5/26/2005	24	218	71%	0%	8%	21%
	6/29/2005	24	181	67%	4%	25%	4%
	7/27/2005	24	84	84%	0%	12%	4%
1ASOT001.65 1 out of 12 samples (8%) exceed 235 cfu/100ml	7/22/2004	19	180	11%	47%	5%	37%
	8/12/2004	3	30	33%	67%	0%	0%
	9/8/2004	24	290	67%	0%	12%	21%
	10/27/2004	24	48	54%	4%	38%	4%
	12/14/2004	24	50	46%	12%	25%	17%
	1/26/2005	24	50	8%	25%	17%	50%
	2/10/2005	7	10	13%	29%	29%	29%
	3/16/2005	7	14	29%	43%	14%	14%
	4/27/2005	8	8	50%	12%	38%	0%
	5/26/2005	24	80	64%	12%	12%	12%
	6/29/2005	24	46	84%	0%	12%	4%
	7/27/2005	24	156	88%	0%	8%	4%
1APOE002.00 0 out of 12 samples (0%) exceed 235 cfu/100ml	7/22/2004	8	60	12%	0%	25%	63%
	8/12/2004	16	130	69%	0%	31%	0%
	9/8/2004	24	60	46%	4%	17%	33%
	10/27/2004	24	12	50%	38%	4%	8%
	12/14/2004	24	40	33%	21%	21%	25%
	1/26/2005	16	24	63%	6%	12%	19%
	2/10/2005	24	46	22%	33%	12%	33%
	3/16/2005	11	10	18%	27%	37%	18%
	4/27/2005	14	28	58%	0%	21%	21%
	5/26/2005	24	68	79%	0%	0%	21%
	6/29/2005	24	68	84%	8%	8%	0%
	7/27/2005	24	70	71%	0%	25%	4%
1AOCC021.35 2 out of 12 samples (17%) exceed 235 cfu/100ml	7/4/2006	3	20	0%	0%	0%	100%
	8/4/2006	8	1	38%	0%	38%	24%
	9/4/2006	24	580	21%	75%	4%	0%
	10/4/2006	24	50	12%	25%	17%	46%
	12/4/2006	24	205	33%	55%	12%	0%
	2/5/2006	2	110	0%	50%	0%	50%
	3/5/2006	24	10	12%	4%	0%	84%
	4/5/2006	24	46	67%	0%	0%	33%

Table 3-12: Results of BST Analysis Conducted in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

VADEQ	Date of Sample	Number of Isolates	E. coli (cfu/ 100ml)	Wildlife	Human	Livestock	Pet
	5/5/2006	1	330	100%	0%	0%	0%
	6/5/2006	11	2	55%	0%	0%	45%
	7/5/2006	24	20	0%	0%	100%	0%
	8/5/2006	3	42	0%	0%	0%	100%
1ALII003.97 2 out of 12 samples (17%) exceed 235 cfu/100ml	7/22/2004	11	120	82%	0%	0%	18%
	8/12/2004	24	6,000	62%	0%	38%	0%
	9/8/2004	16	160	63%	6%	19%	12%
	10/27/2004	24	30	63%	12%	17%	8%
	12/14/2004	24	46	55%	12%	29%	4%
	1/26/2005	24	82	4%	4%	42%	50%
	2/10/2005	24	261	8%	25%	38%	29%
	3/16/2005	10	18	10%	50%	0%	40%
	4/27/2005	22	28	27%	5%	27%	41%
	5/26/2005	24	216	62%	0%	17%	21%
	6/29/2005	18	28	94%	0%	6%	0%
	7/27/2005	24	38	46%	0%	8%	46%
1ABUL010.28 1 out of 12 samples (8%) exceed 235 cfu/100ml	7/4/2006	2	10	50%	50%	0%	0%
	8/4/2006	24	700	75%	0%	21%	4%
	9/4/2006	4	20	100%	0%	0%	0%
	10/4/2006	6	98	50%	50%	0%	0%
	12/4/2006	24	38	62%	21%	0%	17%
	1/5/2006	13	22	8%	8%	31%	53%
	2/5/2006	22	40	36%	18%	5%	41%
	3/5/2006	15	28	20%	53%	20%	7%
	4/5/2006	23	32	61%	4%	22%	13%
	5/5/2006	24	219	71%	8%	21%	0%
	6/5/2006	24	52	100%	0%	0%	0%
	7/5/2006	24	42	88%	0%	8%	4%

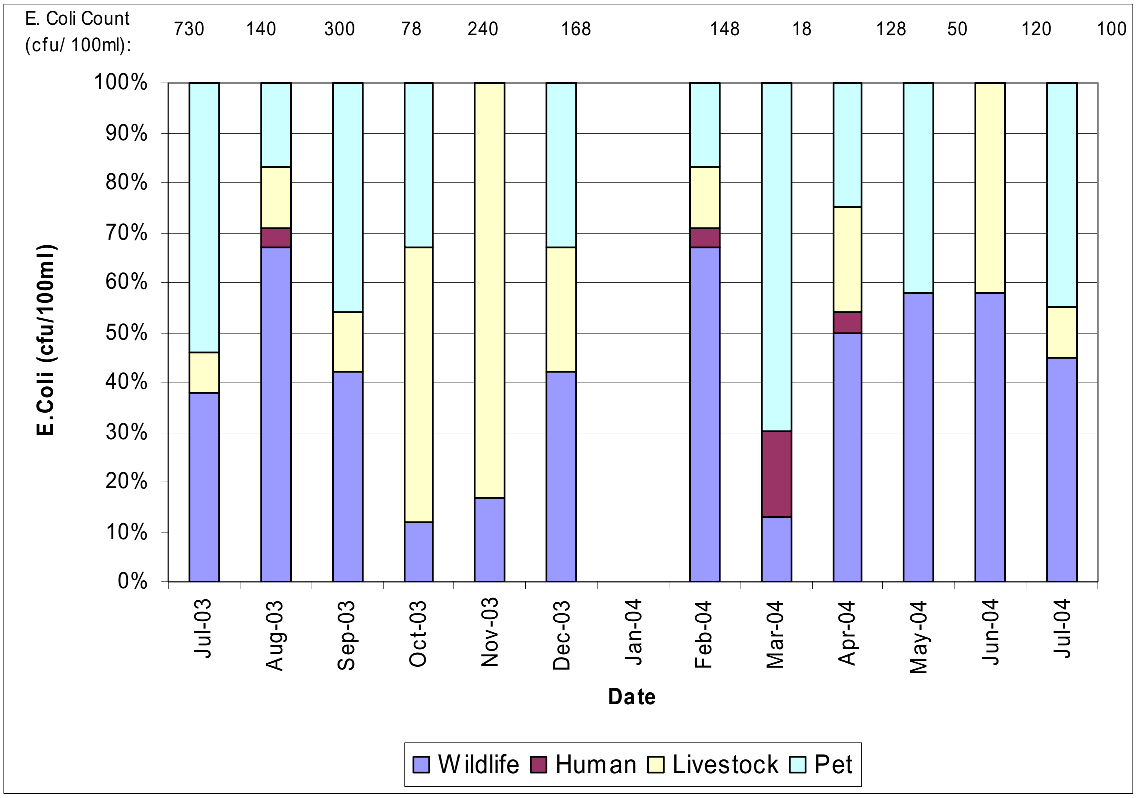

Figure 3-8: BST Source Distributions at Kettle Run 1AKET002.06

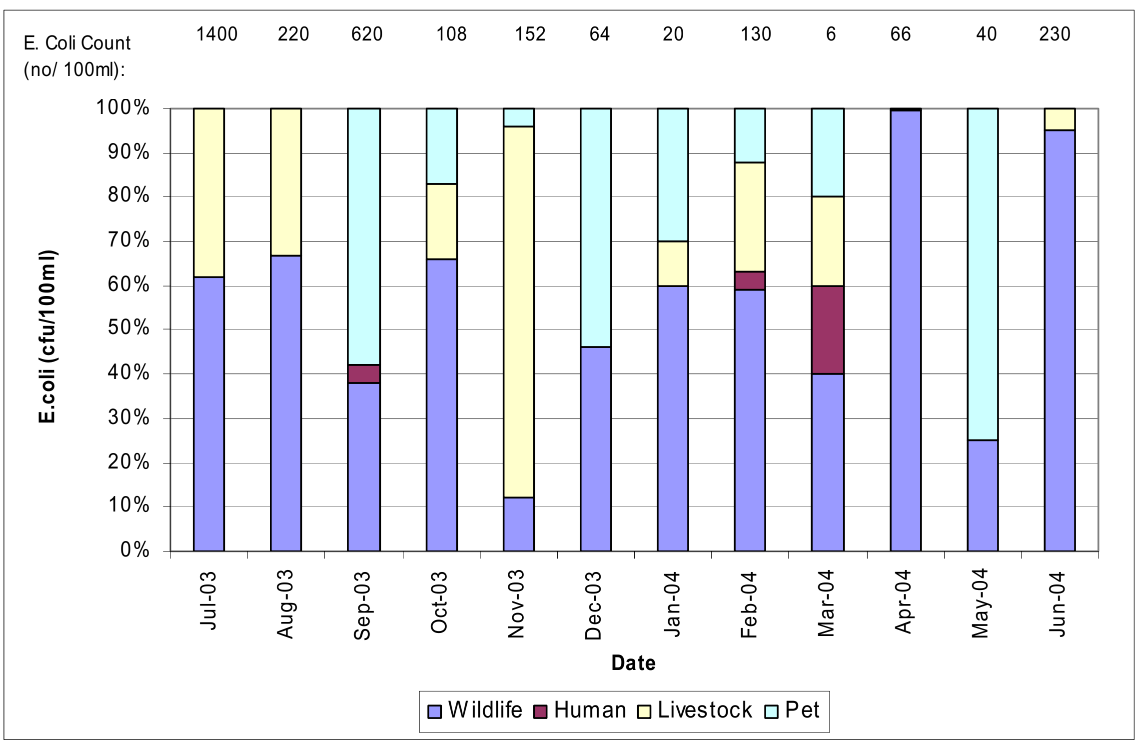

Figure 3-9: BST Source Distributions at Broad Run Station ABRU011.24

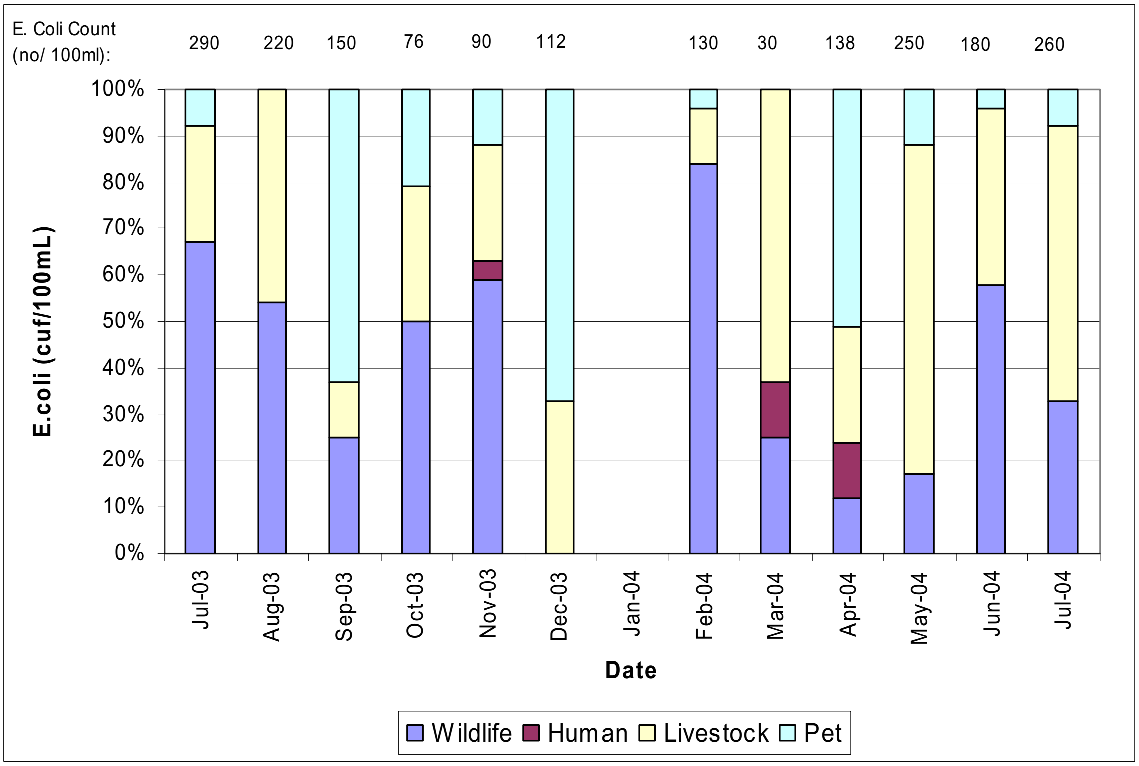

Figure 3-10: BST Source Distributions at Broad Run Station 1ABRU020.12

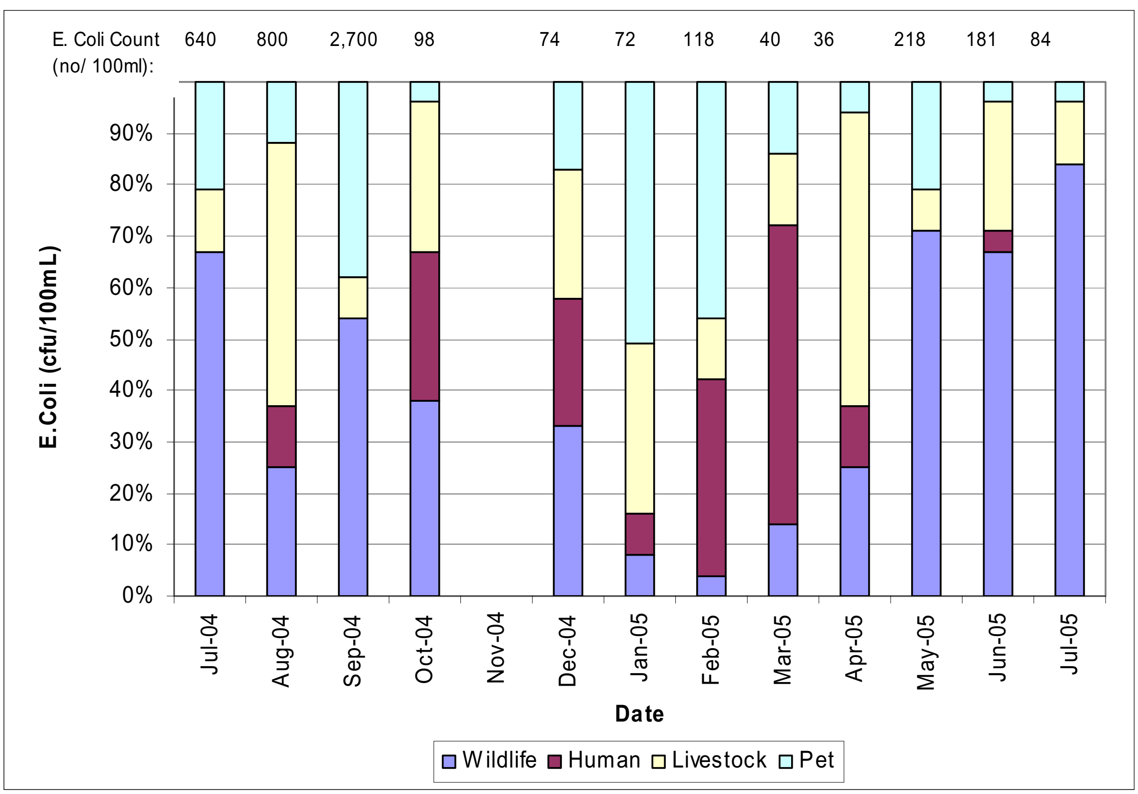

Figure 3-11: BST Source Distributions at Broad Run Station 1ABRU026.40

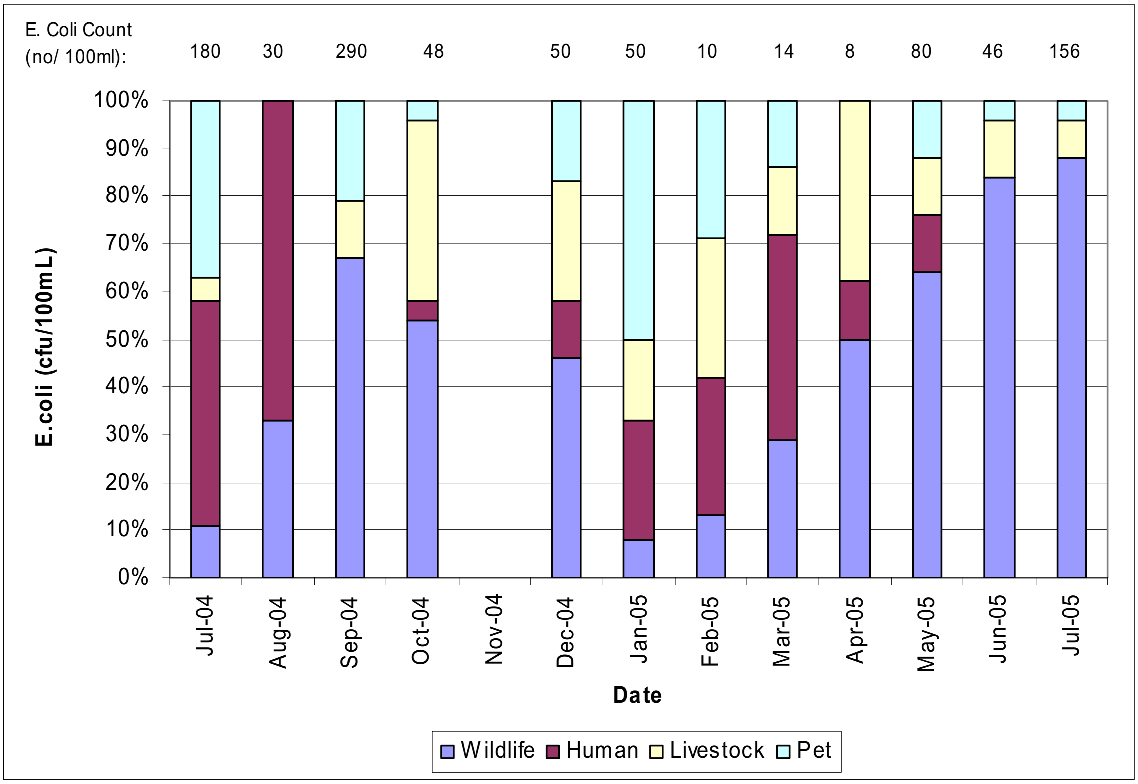

Figure 3-12: BST Source Distributions at South Run Station 1ASOT001.65

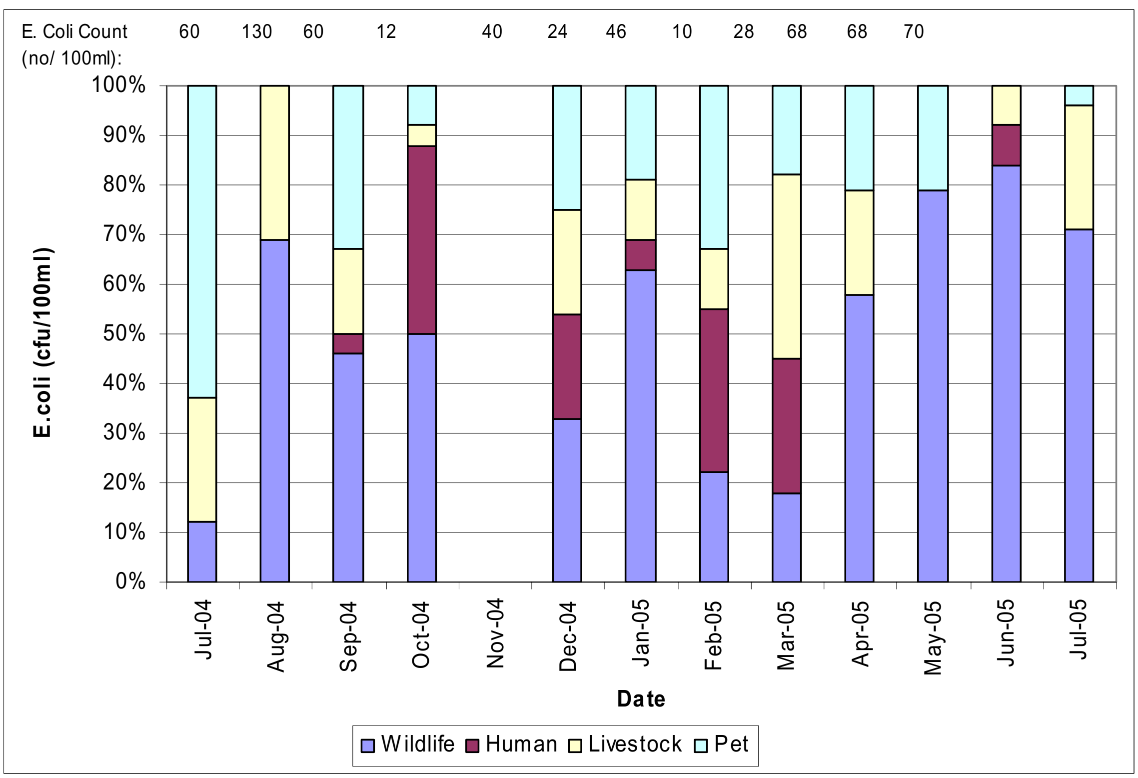

Figure 3-13: BST Source Distributions at Popes Head Station 1APOE002.00

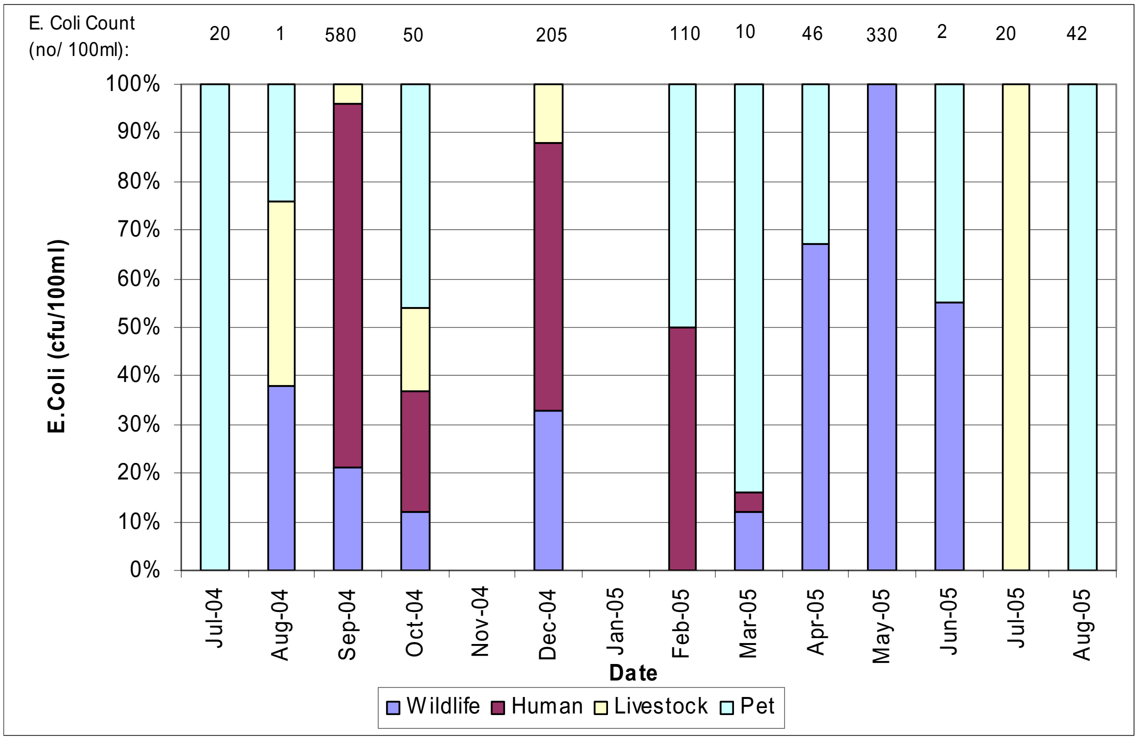

Figure 3-14: BST Source Distribution at Occoquan River Station 1AOCC021.35

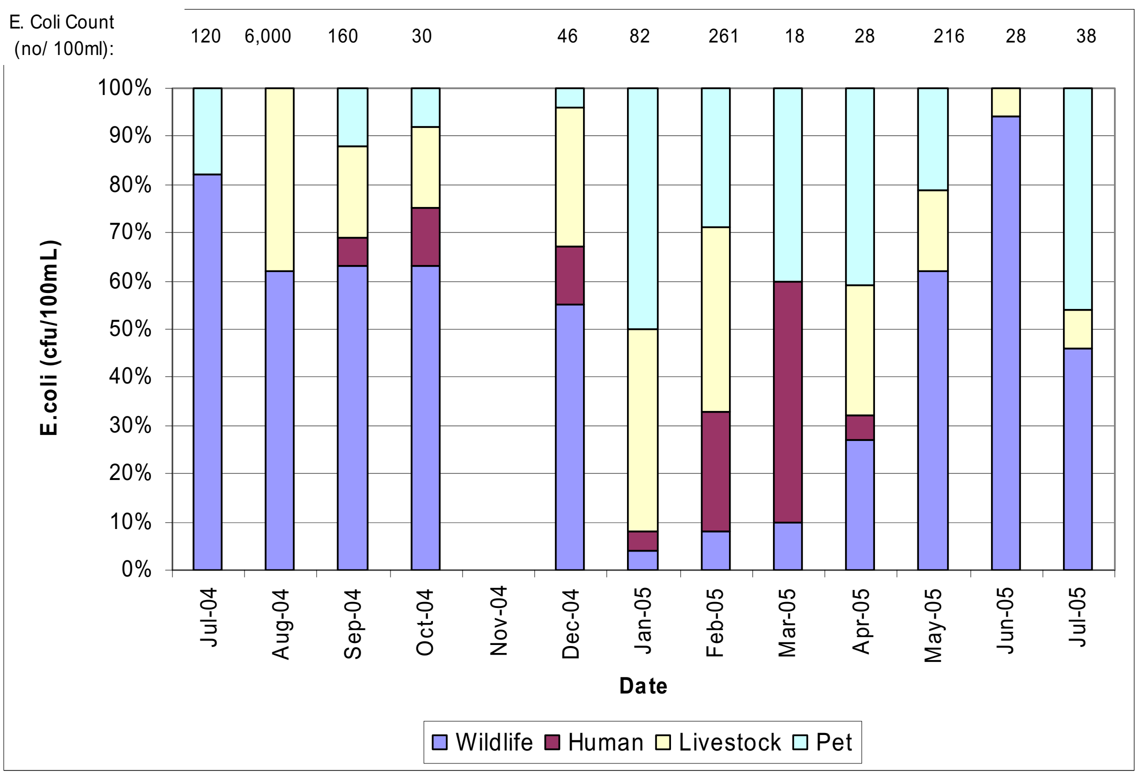

Figure 3-15: BST Source Distribution at Little Bull Run Station 1ALII003.97

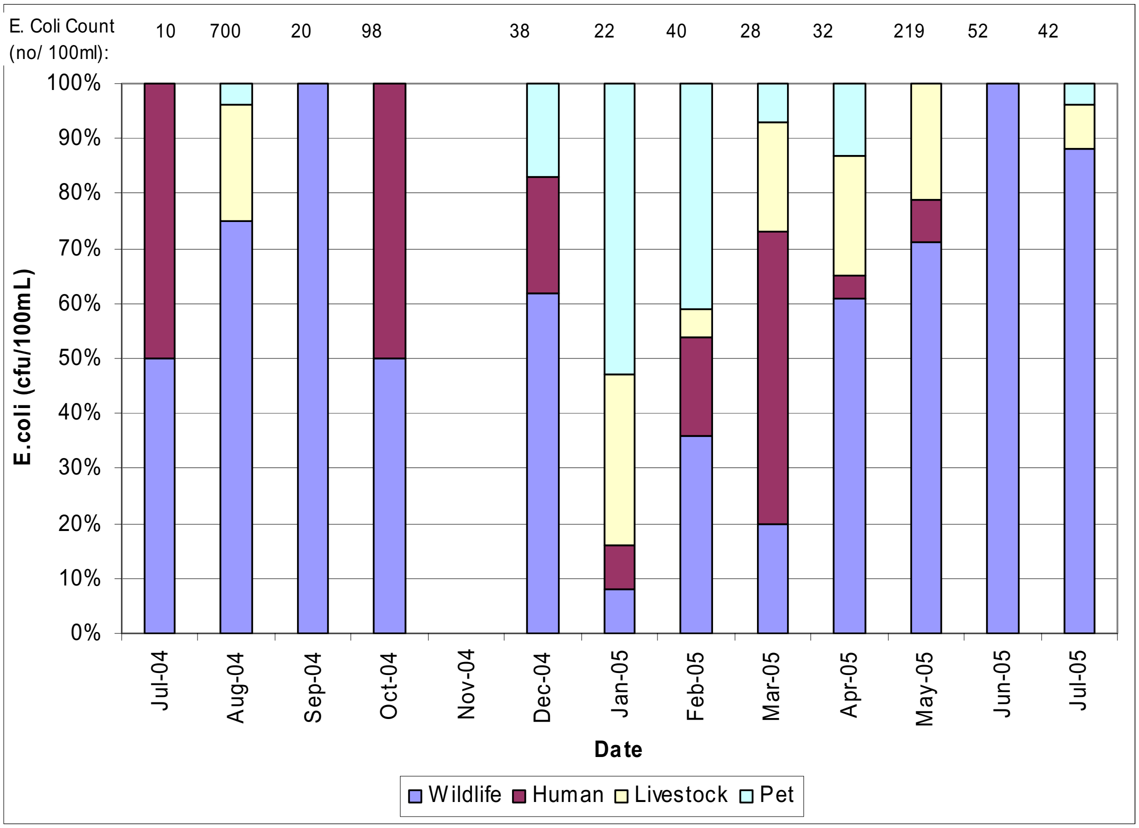

Figure 3-16: BST Source Distribution at Bull Run Station 1ABUL010.28

3.5 Supplemental Water Quality Monitoring Data

3.5.1 Fairfax County Health Department

The Fairfax County Health Department's mission is to protect and improve the health of Fairfax County citizens by preventing or eliminating their exposure to biological, chemical and physical hazards in their present or future environment. As part of this mission, the Division of Environmental Health monitored bacteria water quality parameters regularly throughout Fairfax County until 2004 when the Fairfax County Stormwater Planning Division (SWPD) took over this monitoring. **Figure 3-27** shows the location of the stations sampled within the watershed. **Table 3-13** shows that samples collected between 1986 and 2002 exceeded the geometric mean for fecal coliform bacteria between 24 and 35 percent of the time. Also, 40 to 68 percent of samples collected exceeded the instantaneous maximum criteria for fecal coliform bacteria.

Table 3-13: Fairfax County Health Department Fecal Coliform Data

Station	Stream Sampled	Date Range	No. of Samples	Max (cfu/ 100ml)	Max (cfu/ 100ml	Avg (cfu/ 100ml	Inst. Max[1] Exceedances		Geo. Mean[2] Exceedances	
							No.	%	No.	%
26-2	Popes Head Creek	1986-2002	342	99	6,001	987	165	48%	108	32%
26-3	Piney Branch	1986-2002	346	99	6,001	887	157	45%	103	30%
26-5	Popes Head Creek	1986-2002	340	99	6,001	1,034	169	50%	100	29%
27-1	Johnny More Creek	1986-2002	331	99	6,001	953	160	48%	105	32%
28-1	Little Rocky Run	1986-2002	349	99	6,001	1,274	191	55%	113	32%
28-2	Little Rocky Run	1986-2002	338	99	6,001	930	163	48%	100	30%
29-2	Big Rocky Run	1986-2002	353	99	16,000	1,108	174	49%	107	30%
29-3	Cub Run	1986-2002	354	99	6,001	1,336	201	57%	125	35%
29-4	Cub Run	1986-2002	347	99	6,001	969	150	43%	97	28%
29-5	Fatlick Branch	1986-2002	347	99	6,001	1,195	180	52%	118	34%
29-6	Fatlick Branch	1986-2002	354	99	6,001	1,033	182	51%	111	31%
29-7	Elklick Branch	2000-2002	53	99	3,700	868	36	68%	17	32%
29-8	Cub Run	1986-	351	99	6,001	891	153	44%	97	28%

Table 3-13: Fairfax County Health Department Fecal Coliform Data										
Station	Stream Sampled	Date Range	No. of Samples	Max (cfu/ 100ml)	Max (cfu/ 100ml	Avg (cfu/ 100ml	Inst. Max[1] Exceedances		Geo. Mean[2] Exceedances	
							No.	%	No.	%
		2002								
29-9	Cub Run	2000-2002	50	99	1,800	568	27	54%	12	24%
30-1	Bull Run	1986-2002	357	99	6,001	862	143	40%	95	27%

[1] Instantaneous maximum *E.coli* bacteria concentration of 235/100 ml

[2] Geometric mean fecal *E.coli* bacteria concentration of 126/100 ml, of water for two or more samples taken during any calendar month.

3.5.2 Prince William County Data

Prince William County Department of Public Works conducted a study to monitor and identify the sources of fecal pollution due to high *E. coli* concentrations. Between June 2004 and June 2005, one station on each stream was sampled for *E. coli* monitoring and microbial source tracking. Results were determined based on techniques including antibiotic resistance analysis and gel electrophoresis (DNA fingerprinting technique). Results from the *E. coli* source classifications indicated that there was an overall absence of a human signature in samples, livestock was considered a minor source of pollution, pets (mainly dogs) left a signature at most sites and were considered a secondary source of pollution, and wildlife and birds were considered the dominant source of pollution at the majority of sites (VA Tech, 2005). **Figure 3-27** shows the location of monitoring sites and **Table 3-14** and **Figures 3-17** to **3-26** shows the results of the microbial source tracking.

Table 3-14:Prince William County BST Data						
Station	Date Sampled	Total No. Isolates	Human	Livestock	Pets	Wildlife
Upper Bull Run-Blackburn's Ford (Rt 28) (PWC-BST 1)*	4-Jun	24	0.0%	16.7%	4.2%	79.2%
	4-Jul	24	0.0%	0.0%	83.3%	16.7%
	4-Aug	23	0.0%	0.0%	25.0%	70.8%
	4-Sep	24	0.0%	0.0%	37.5%	62.5%
	4-Oct	24	4.2%	0.0%	25.0%	70.8%
	4-Nov	23	0.0%	0.0%	58.3%	37.5%
	4-Dec	24	0.0%	45.8%	16.7%	37.5%
	5-Jan	24	0.0%	12.5%	12.5%	75.0%
	5-Feb	24	0.0%	29.2%	33.3%	58.3%
	5-Mar	24	12.5%	0.0%	37.5%	50.0%

Table 3-14:Prince William County BST Data						
Station	Date Sampled	Total No. Isolates	Human	Livestock	Pets	Wildlife
	5-Apr	20	20.0%	41.7%	4.2%	20.8%
	5-May	24	4.2%	45.8%	16.7%	33.3%
	5-Jun	23	0.0%	0.0%	0.0%	95.8%
Lower Bull Run-Marina (Yates Ford Road) (PWC-BST 2)*	4-Jun	4	25.0%	4.2%	0.0%	8.3%
	4-Jul	24	4.2%	16.7%	29.2%	54.2%
	4-Aug	24	8.3%	4.2%	20.8%	66.7%
	4-Sep	22	0.0%	0.0%	54.2%	37.5%
	4-Oct	19	5.3%	0.0%	20.8%	54.2%
	4-Nov	16	12.5%	0.0%	37.5%	20.8%
	4-Dec	18	0.0%	0.0%	25.0%	50.0%
	5-Jan	24	0.0%	4.2%	20.8%	75.0%
	5-Feb	24	0.0%	12.5%	25.0%	62.5%
	5-Mar	24	4.2%	37.5%	37.5%	16.7%
	5-Apr	23	4.3%	33.3%	12.5%	45.8%
	5-May	24	4.2%	12.5%	33.3%	50.0%
	5-Jun	23	0.0%	4.2%	33.3%	58.3%
Youngs Branch, Sudley Road (PWC-BST 3)*	4-Jun	7	0.0%	8.3%	0.0%	20.8%
	4-Jul	24	4.2%	41.7%	4.2%	50.0%
	4-Aug	24	0.0%	12.5%	8.3%	79.2%
	4-Sep	24	0.0%	50.0%	4.2%	45.8%
	5-Oct	24	0.0%	41.7%	4.2%	54.2%
	5-Nov	24	0.0%	0.0%	29.2%	70.8%
	5-Dec	24	0.0%	20.8%	50.0%	29.2%
	5-Jan	24	0.0%	45.8%	29.2%	25.0%
	5-Feb	24	0.0%	41.7%	4.2%	54.2%
	5-Mar	24	4.2%	37.5%	20.8%	33.3%
	5-Apr	24	0.0%	58.3%	4.2%	37.5%
	5-May	24	4.2%	50.0%	16.7%	29.2%
	5-Jun	23	4.3%	4.2%	37.5%	54.2%
Catharpin Run, Robin Drive (PWC-BST 4)*	4-Jun	23	0.0%	45.8%	4.2%	41.7%
	4-Jul	24	0.0%	41.7%	25.0%	33.3%
	4-Aug	24	0.0%	0.0%	20.8%	79.2%
	4-Sep	24	4.2%	0.0%	20.8%	75.0%
	5-Oct	24	0.0%	0.0%	16.7%	83.3%
	5-Nov	24	8.3%	0.0%	25.0%	66.7%
	5-Dec	24	0.0%	83.3%	4.2%	12.5%
	5-Jan	24	8.3%	20.8%	20.8%	50.0%
	5-Feb	24	8.3%	8.3%	29.2%	54.2%
	5-Mar	24	4.2%	54.2%	12.5%	29.2%
	5-Apr	24	4.2%	66.7%	12.5%	16.7%
	5-May	24	0.0%	66.7%	12.5%	20.8%
	5-Jun	23	4.3%	0.0%	16.7%	75.0%
Buckhall	4-Jun	24	8.3%	33.3%	12.5%	45.8%

Table 3-14:Prince William County BST Data						
Station	Date Sampled	Total No. Isolates	Human	Livestock	Pets	Wildlife
Branch, Signal Hill Road (PWC-BST 5)*	4-Jul	24	4.2%	33.3%	0.0%	62.5%
	4-Aug	24	4.2%	45.8%	0.0%	50.0%
	4-Sep	24	8.3%	37.5%	4.2%	50.0%
	5-Oct	24	12.5%	25.0%	20.8%	41.7%
	5-Nov	24	0.0%	33.3%	20.8%	45.8%
	5-Dec	24	0.0%	29.2%	0.0%	70.8%
	5-Jan	24	12.5%	29.2%	12.5%	45.8%
	5-Feb	24	12.5%	25.0%	25.0%	37.5%
	5-Mar	24	4.2%	37.5%	0.0%	58.3%
	5-Apr	24	8.3%	41.7%	8.3%	41.7%
	5-May	24	12.5%	29.2%	25.0%	33.3%
	5-Jun	24	0.0%	41.7%	8.3%	50.0%
Flat Branch, Lomond Drive (PWC-BST 6)*	4-Jun	20	10.0%	0.0%	25.0%	50.0%
	4-Jul	24	16.7%	0.0%	41.7%	41.7%
	4-Aug	24	25.0%	4.2%	33.3%	37.5%
	4-Sep	24	54.2%	0.0%	16.7%	29.2%
	5-Oct	24	41.7%	0.0%	8.3%	50.0%
	5-Nov	24	20.8%	8.3%	29.2%	41.7%
	5-Dec	24	12.5%	4.2%	25.0%	58.3%
	5-Jan	24	20.8%	8.3%	37.5%	33.3%
	5-Feb	24	29.2%	0.0%	33.3%	37.5%
	5-Mar	24	33.3%	4.2%	16.7%	45.8%
	5-Apr	24	58.3%	8.3%	8.3%	25.0%
	5-May	24	29.2%	12.5%	25.0%	33.3%
	5-Jun	24	16.7%	4.2%	33.3%	45.8%
South Run, Buckland Mill Road (PWC-BST 7)*	4-Jun	8	0.0%	8.3%	4.2%	20.8%
	4-Jul	20	0.0%	25.0%	4.2%	54.2%
	4-Aug	24	4.2%	16.7%	0.0%	79.2%
	4-Sep	24	0.0%	33.3%	4.2%	62.5%
	5-Oct	24	0.0%	29.2%	16.7%	54.2%
	5-Nov	24	0.0%	20.8%	0.0%	79.2%
	5-Dec	24	4.2%	25.0%	20.8%	50.0%
	5-Jan	24	0.0%	29.2%	8.3%	62.5%
	5-Feb	15	6.7%	33.3%	0.0%	25.0%
	5-Mar	24	0.0%	37.5%	25.0%	37.5%
	5-Apr	24	4.2%	37.5%	16.7%	41.7%
	5-May	20	0.0%	50.0%	8.3%	25.0%
	5-Jun	24	4.2%	54.2%	8.3%	33.3%
Broad Run, Route 28 (PWC-BST 8)*	4-Jun	8	0.0%	8.3%	8.3%	16.7%
	4-Jul	24	0.0%	0.0%	58.3%	41.7%
	4-Aug	24	0.0%	4.2%	66.7%	29.2%
	4-Sep	23	0.0%	0.0%	20.8%	75.0%
	5-Oct	24	4.2%	0.0%	25.0%	70.8%

Table 3-14:Prince William County BST Data						
Station	Date Sampled	Total No. Isolates	Human	Livestock	Pets	Wildlife
	5-Nov	14	0.0%	4.2%	16.7%	37.5%
	5-Dec	23	0.0%	0.0%	33.3%	62.5%
	5-Jan	23	4.3%	8.3%	20.8%	62.5%
	5-Feb	24	0.0%	20.8%	8.3%	70.8%
	5-Mar	23	13.0%	0.0%	41.7%	41.7%
	5-Apr	24	12.5%	12.5%	20.8%	54.2%
	5-May	23	8.7%	12.5%	41.7%	33.3%
	5-Jun	23	4.3%	0.0%	33.3%	58.3%
Lower Kettle Run, Valley View Road (PWC-BST 9)*	4-Jun	24	8.3%	12.5%	8.3%	70.8%
	4-Jul	24	0.0%	25.0%	25.0%	50.0%
	4-Aug	24	0.0%	37.5%	20.8%	41.7%
	4-Sep	24	8.3%	20.8%	16.7%	54.2%
	5-Oct	24	4.2%	20.8%	20.8%	58.3%
	5-Nov	24	4.2%	29.2%	16.7%	50.0%
	5-Dec	24	0.0%	20.8%	16.7%	62.5%
	5-Jan	24	0.0%	8.3%	16.7%	75.0%
	5-Feb	24	0.0%	16.7%	16.7%	66.7%
	5-Mar	24	8.3%	37.5%	12.5%	41.7%
	5-Apr	24	0.0%	50.0%	20.8%	29.2%
	5-May	24	0.0%	41.7%	20.8%	37.5%
	5-Jun	24	4.2%	16.7%	33.3%	50.0%
Upper Kettle Run, Reid Lane (PWC-BST 10)*	4-Jun	22	0.0%	29.2%	25.0%	37.5%
	4-Jul	24	12.5%	41.7%	12.5%	33.3%
	4-Aug	20	10.0%	33.3%	12.5%	45.8%
	4-Sep	24	0.0%	41.7%	20.8%	37.5%
	5-Oct	24	8.3%	33.3%	16.7%	41.7%
	5-Nov	24	4.2%	45.8%	8.3%	41.7%
	5-Dec	18	0.0%	25.0%	12.5%	37.5%
	5-Jan	24	8.3%	29.2%	20.8%	41.7%
	5-Feb	24	0.0%	25.0%	33.3%	41.7%
	5-Mar	24	4.2%	33.3%	25.0%	37.5%
	5-Apr	24	4.2%	33.3%	4.2%	58.3%
	5-May	24	8.3%	29.2%	20.8%	50.0%
	5-Jun	24	4.2%	29.2%	16.7%	50.0%

* Station IDs were generated for display purposes

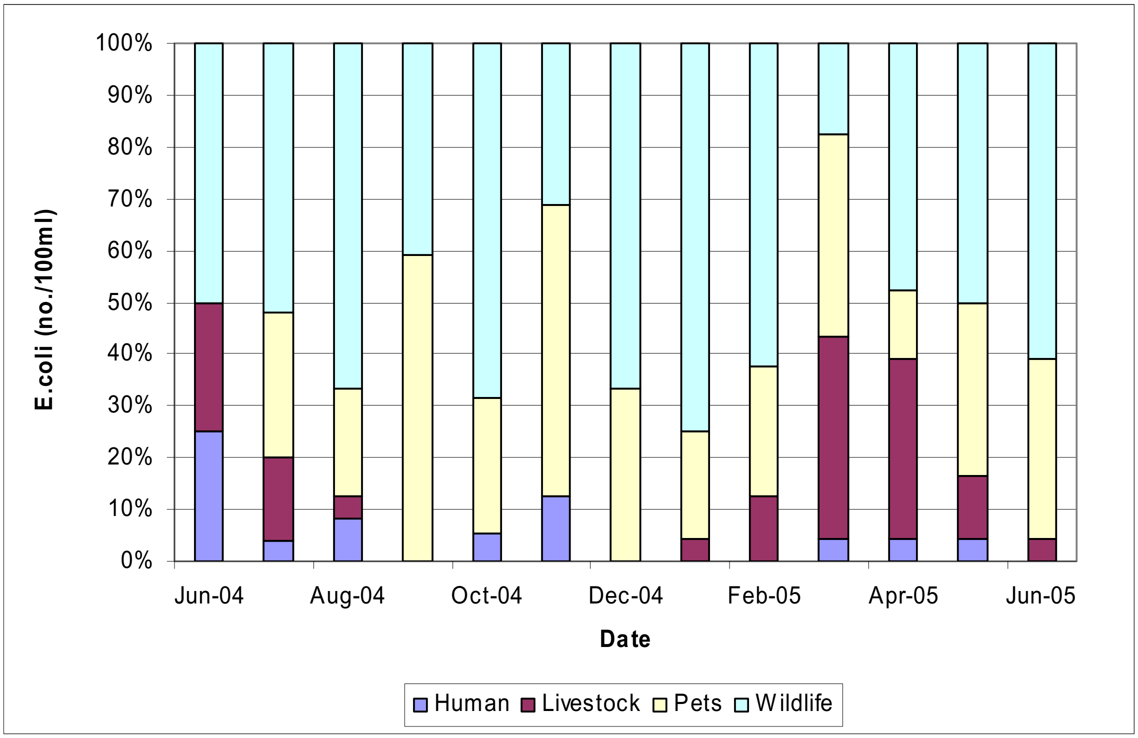

Figure 3-17: Prince William County BST Source Distribution in Lower Bull Run

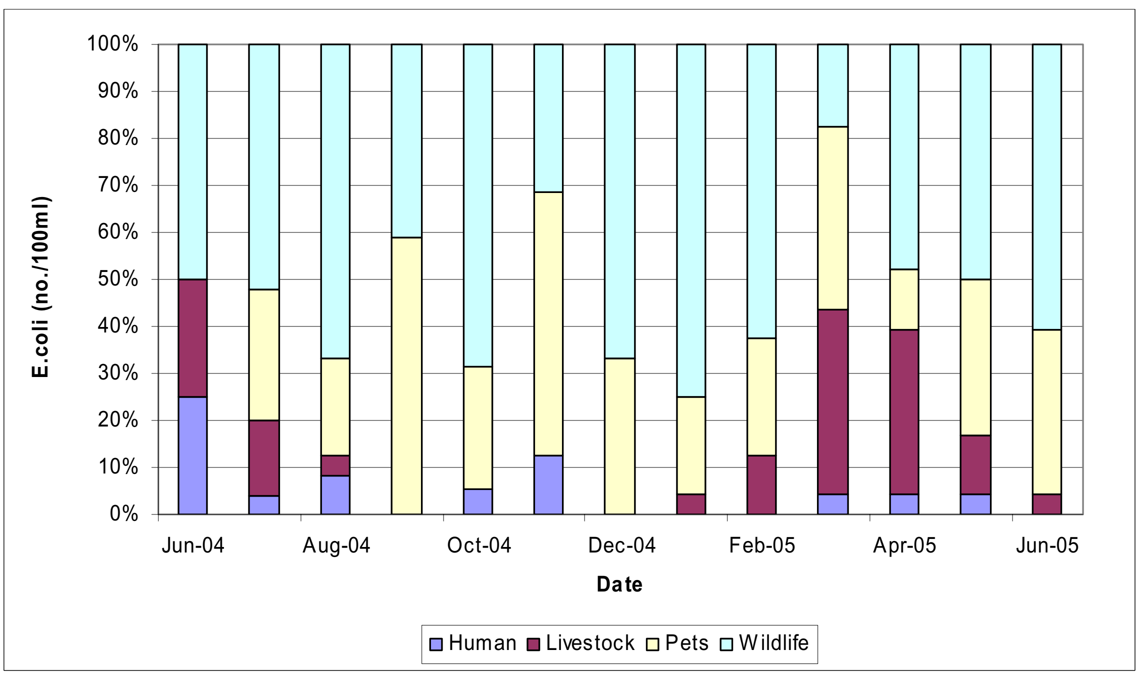

Figure 3-18: Prince William County BST Source Distribution in Young's Branch

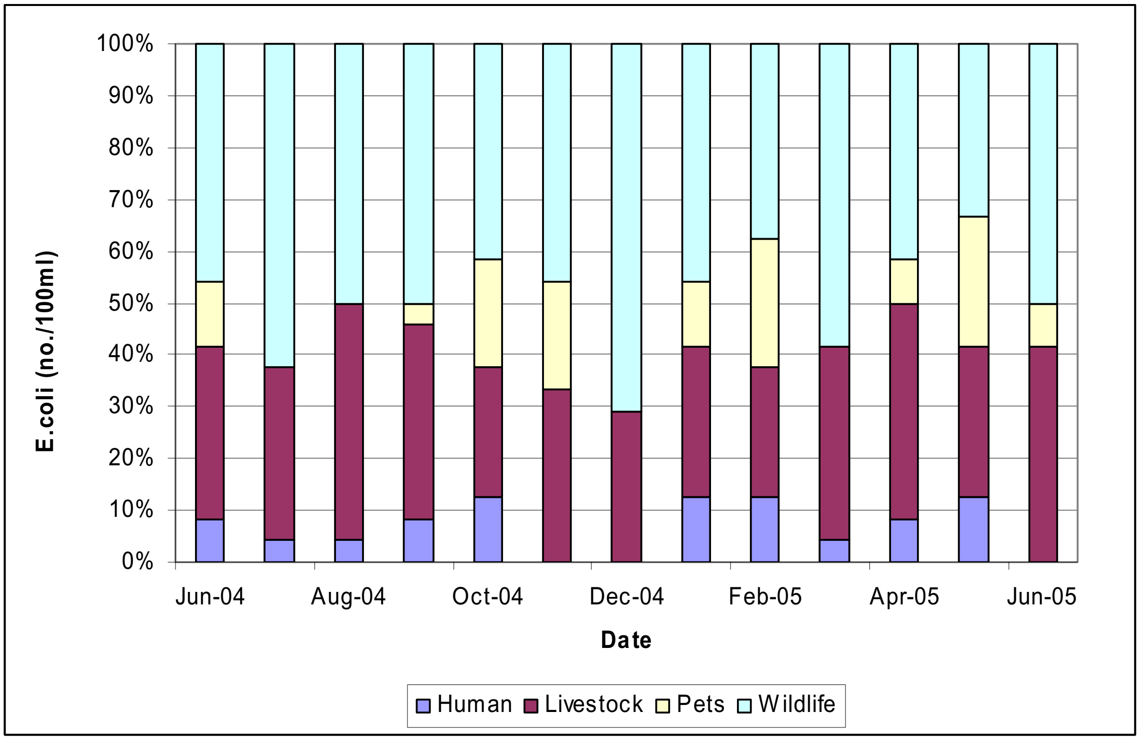

Figure 3-19: Prince William County BST Source Distribution in Buckhall Branch

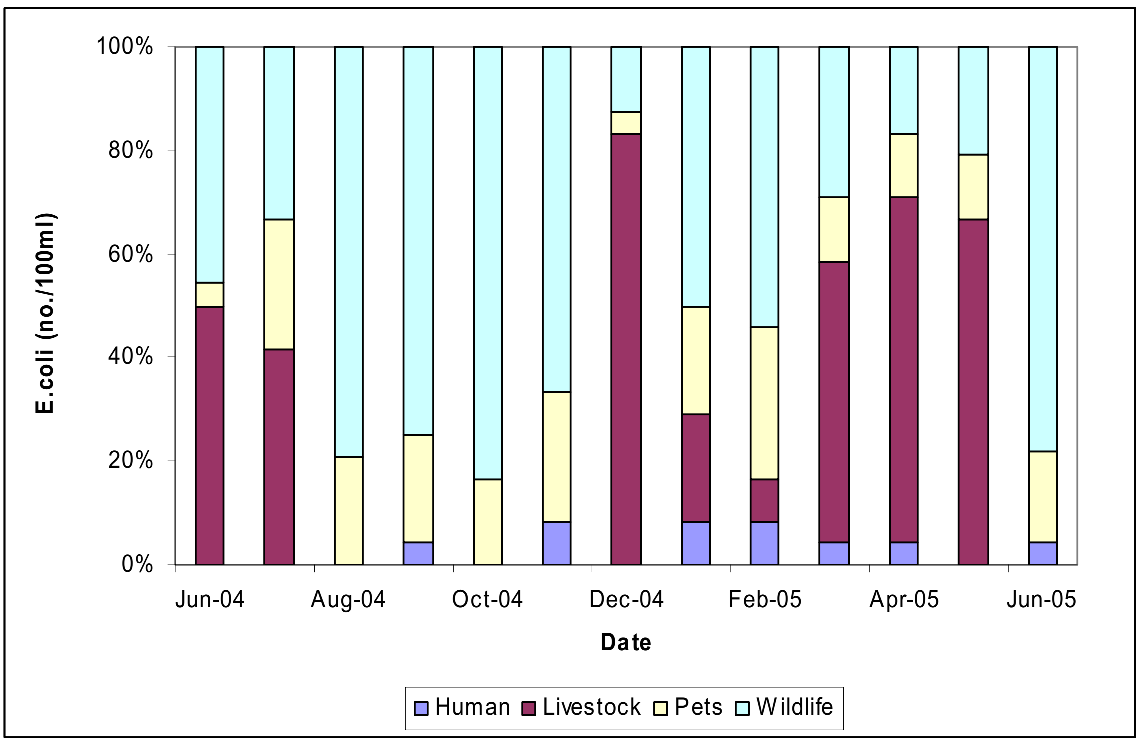

Figure 3-20: Prince William County BST Source Distribution in Catharpin Creek

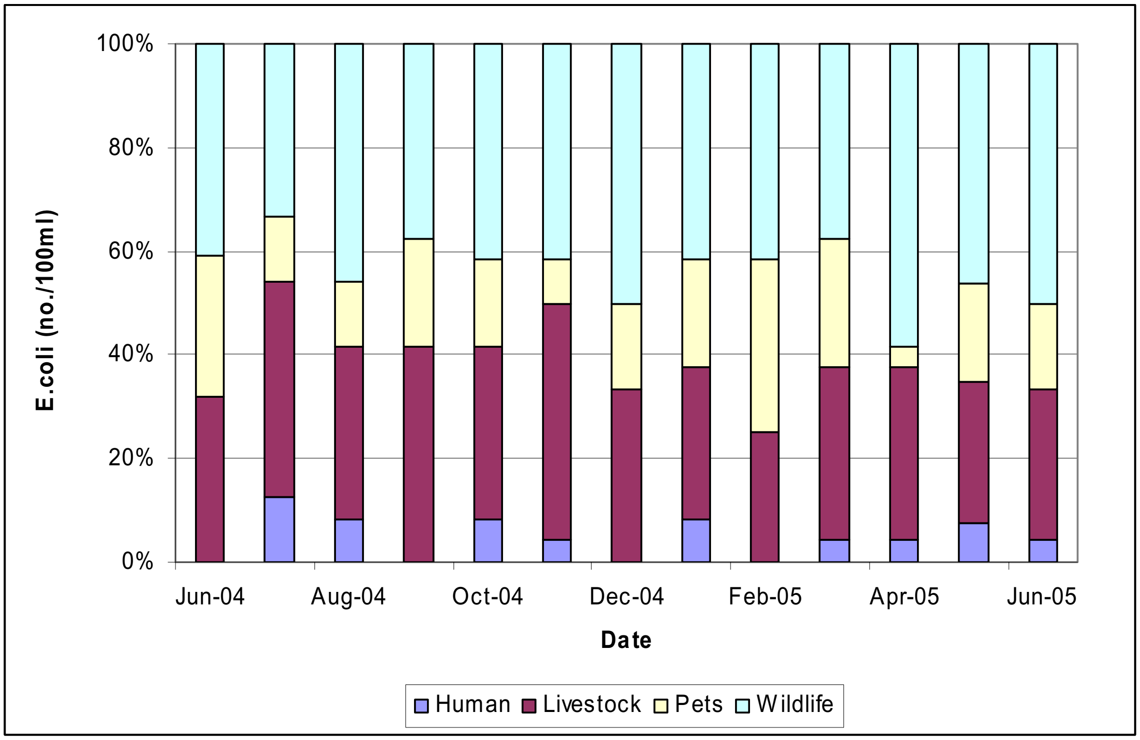

Figure 3-21: Prince William County BST Source Distribution in Upper Kettle Run

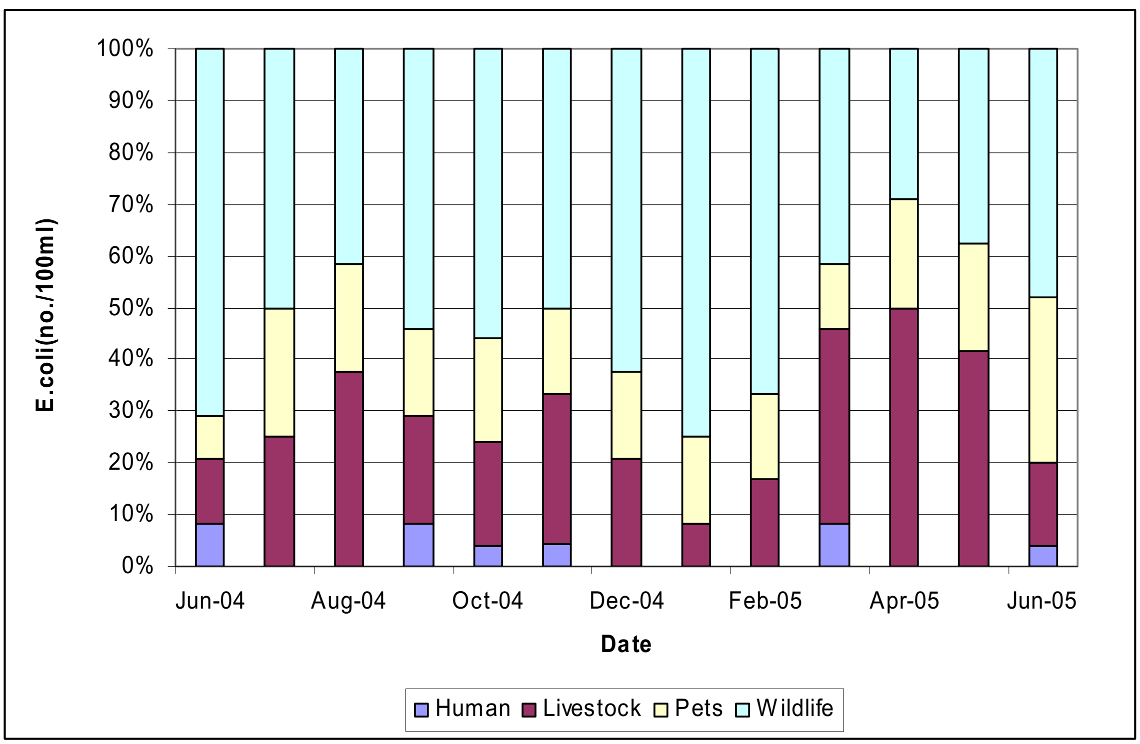

Figure 3-22: Prince William County BST Source Distribution in Lower Kettle Run

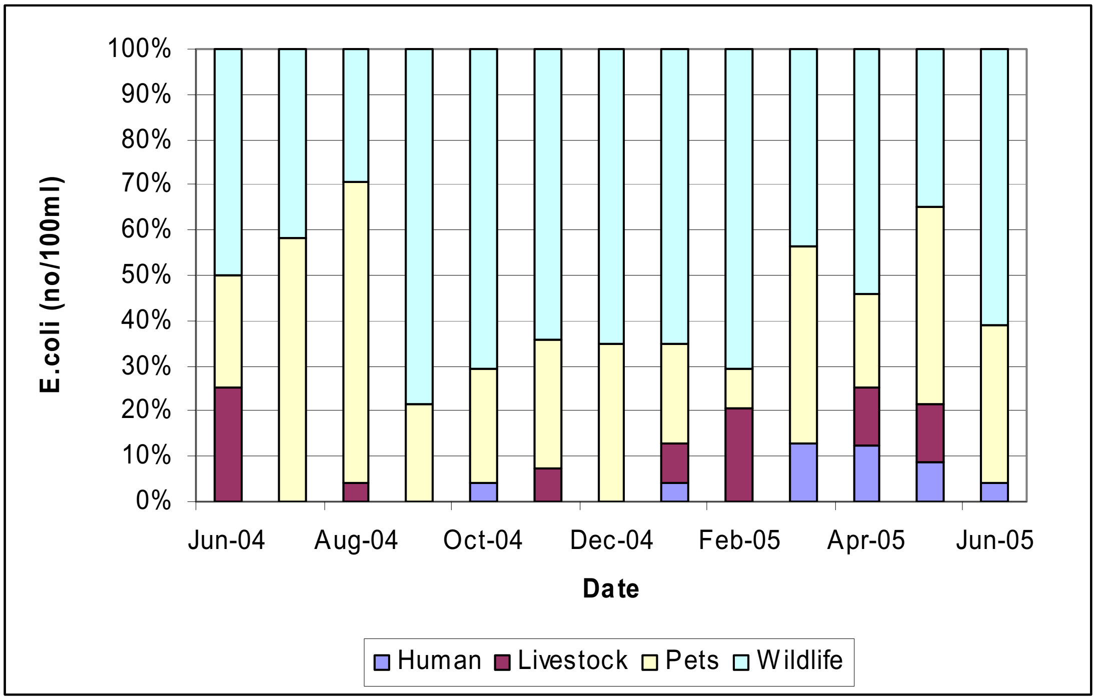

Figure 3-23: Prince William County BST Source Distribution in Broad Run

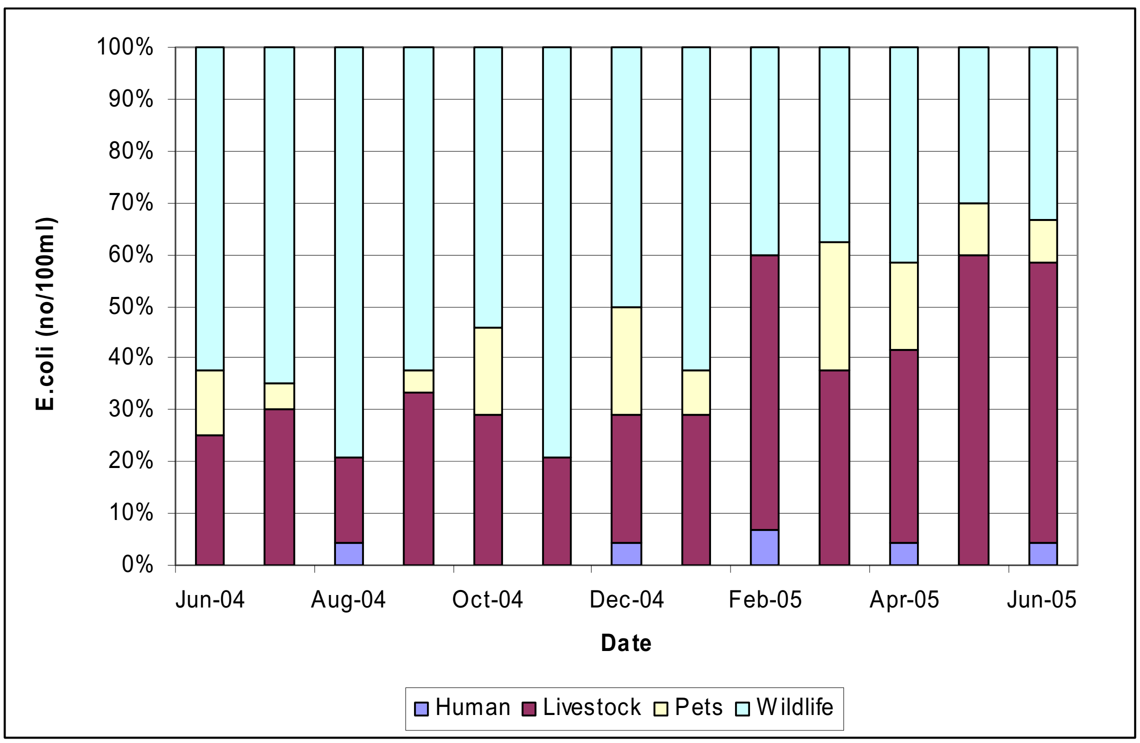

Figure 3-24: Prince William County BST Source Distribution in South Run

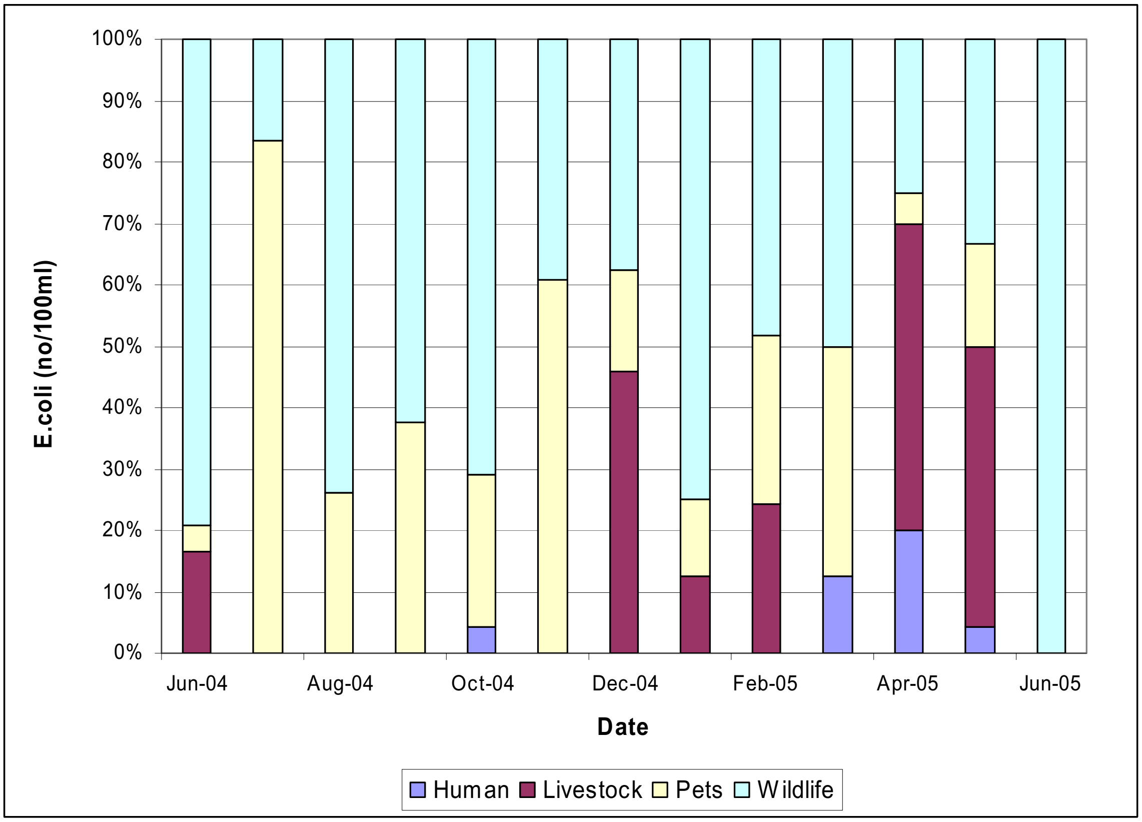

Figure 3-25: Prince William County BST Source Distribution in Upper Bull Run

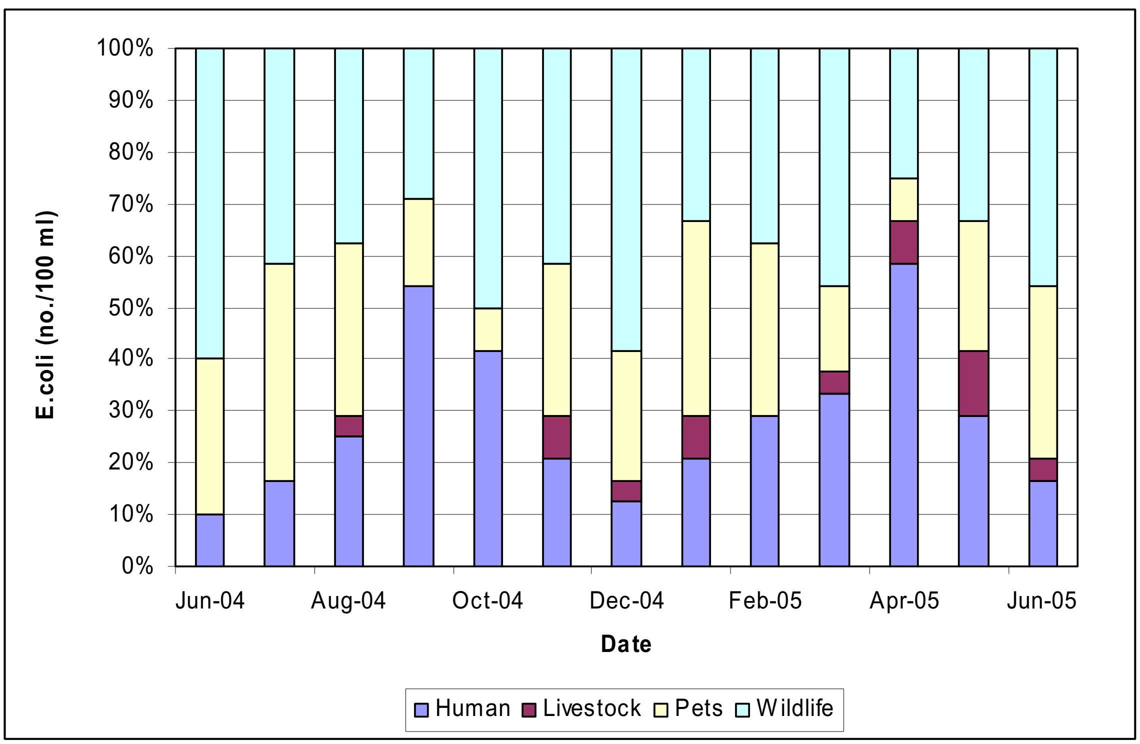

Figure 3-26: Prince William County BST Source Distribution in Flat Branch

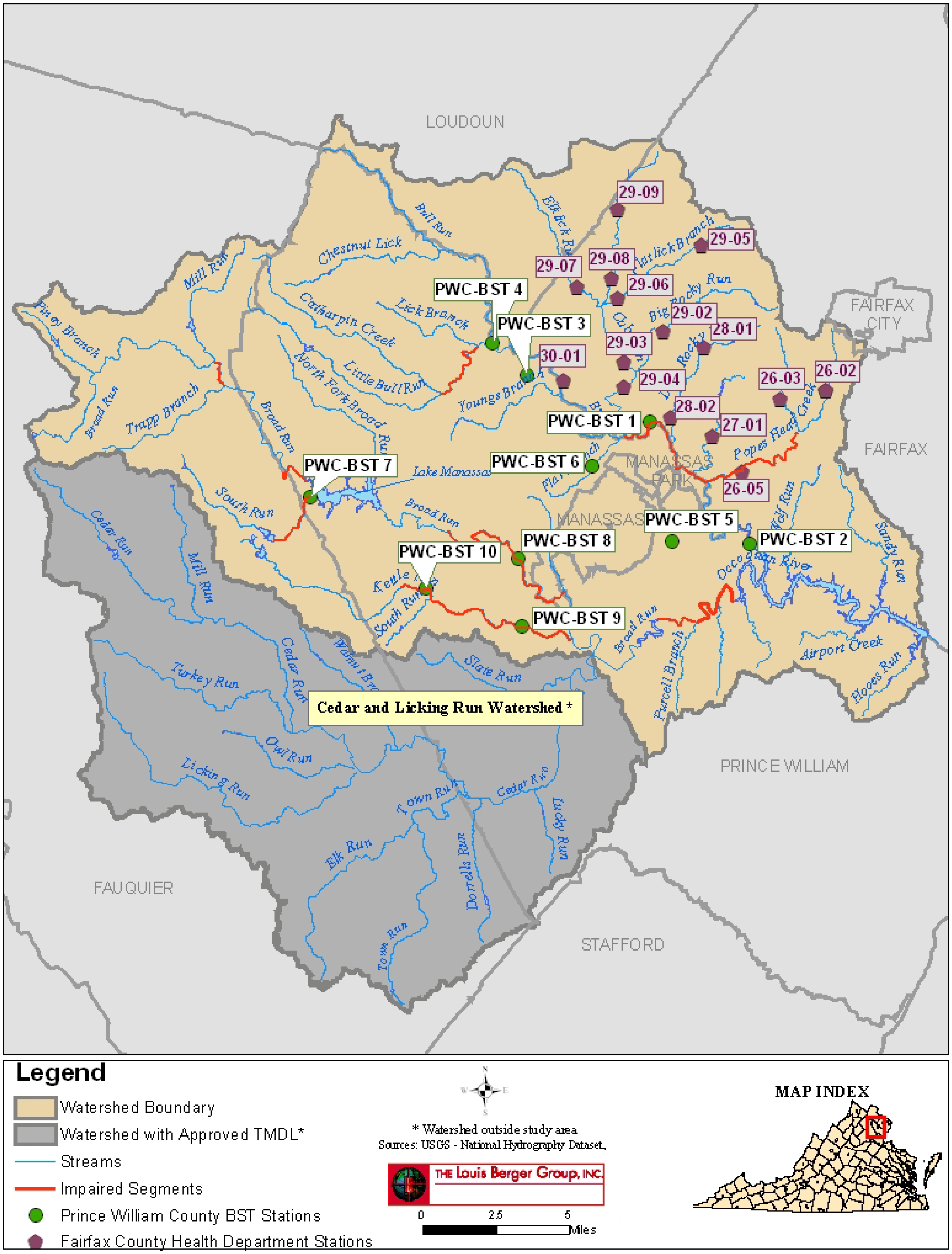

Figure 3-27: Supplemental Water Quality Monitoring Stations Located in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds

3.5.3 Upper Occoquan Sewage Authority Water Quality Data

The Upper Occoquan Sewage Authority (UOSA) is the largest permitted discharger in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed. In addition to its discharge monitoring requirements, UOSA also monitors instream water quality on Bull Run upstream from its discharge at Old Centreville Road (OCR) and downstream of its discharge at Route 28. Sample *E. coli* data from January 2004 to September 2005 was provided by UOSA for this study, and inventory of this data is presented in **Table 3-15**.

Table 3-15: UOSA Instream Bacteria Data

Date	E coli (MPN/100 mL)*	
	OCR	Route 28
2/2/2004	47.1	25.9
3/1/2004	47.9	14.6
4/5/2004	129.1	119.8
5/3/2004	**1732.9**	**1203.3**
6/7/2004	**648.8**	**461.1**
7/12/2004	127.4	88.0
8/2/2004	**4196.0**	**2419.6**
9/13/2004	228.2	35.5
10/4/2004	204.6	36.8
11/1/2004	78.0	19.7
12/6/2004	82.0	19.5
1/3/2005	35.9	26.9
2/7/2005	38.9	<1.0
3/7/2005	35.0	39.3
4/4/2005	218.7	**248.1**
5/2/2005	**648.8**	143.9
6/6/2005	135.4	76.3
7/11/2005	112.4	81.6
8/8/2005	99.0	15.6
9/12/2005	146.7	56.5

*Note: Values in **bold** indicate exceedences of the instantaneous maximum *E.coli* bacteria concentration of 235/100 ml

3.6 Fecal Coliform Source Assessment

This section focuses on characterizing the sources that potentially contribute to the fecal coliform loading in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, wildlife, pets, and land application of manure and biosolids. Chapter 4 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.6.1 Permitted Facilities

Data obtained from the DEQ's Northern Regional Office indicate that there are 15 individually permitted facilities and 67 domestic sewage general permits located in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed. The permit number, design flow, and status for each permit are presented in **Table 3-16**. The permitted flows for the domestic general permits are established at 1,000 gallons per day. The locations of the individual permits are presented in **Figure 3-28** (latitudes and longitudes were not consistently available for the general permits and they could not be mapped). The flow from all permitted dischargers will be considered in model setup and calibration.

Table 3-16: Permitted Discharges in the Road Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

Permit No.	Facility Name	Facility Type	Design Flow (GPD)[1]
VA0020460	Vint Hill Farms Station WWTP	Municipal	246,000
VA0024988	UOSA - Centreville	Municipal	64,000,000
VA0029092	New Baltimore Shell	Municipal	10,000
VA0050181	Manassas City WTP	Industrial	903,000
VA0051683	Colonial Pipeline - Chantilly	Industrial	440,000
VA0051691	Colonial Pipeline - Bull Run	Industrial	60,000
VA0064157	Town and Country Restaurant	Municipal	15,000
VA0085901	IBM Corp	Industrial	504,000
VA0087700	Atlantic Research Corp - Gainesville	Industrial	14,000,000
VA0087858	Sunoco - Manassas Terminal	Industrial	2,215,000
VA0087891	Evergreen Country Club	Municipal	7,500
VA0088510	Prince William County - Balls Ford Yard Waste	Industrial	200,000
VA0089541	MWAA - Washington Dulles Int'l Airport	Industrial	-
VA0091430	Loudoun Composting	Industrial	-
VA0090441	Adaptive Concrete Solutions	Industrial	-

Table 3-16: Permitted Discharges in the Road Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed			
Permit No.	**Facility Name**	**Facility Type**	**Design Flow (GPD)[1]**
VAG406009	Domestic Sewage Discharge	Residence	95
VAG406038	Domestic Sewage Discharge	Residence	450
VAG406040	Domestic Sewage Discharge	Residence	500
VAG406065	Domestic Sewage Discharge	Residence	300
VAG406071	Domestic Sewage Discharge	Residence	600
VAG406079	Domestic Sewage Discharge	Residence	400
VAG406134	Domestic Sewage Discharge	Residence	300
VAG406162	Domestic Sewage Discharge	Residence	500
VAG406165	Domestic Sewage Discharge	Residence	450
VAG406174	Domestic Sewage Discharge	Residence	800
VAG406221	Domestic Sewage Discharge	Residence	600
VAG406224	Domestic Sewage Discharge	Residence	450
VAG406231	Domestic Sewage Discharge	Residence	450
VAG406233	Domestic Sewage Discharge	Commercial	1,000
VAG406234	Domestic Sewage Discharge	Residence	100
VAG406236	Domestic Sewage Discharge	Residence	450
VAG406240	Domestic Sewage Discharge	Commercial	1,000
VAG406247	Domestic Sewage Discharge	Residence	450
VAG406259	Domestic Sewage Discharge	Residence	600
VAG406260	Domestic Sewage Discharge	Residence	600
VAG406270	Domestic Sewage Discharge	Residence	260
VAG406271	Domestic Sewage Discharge	Residence	600
VAG406292	Domestic Sewage Discharge	Residence	750
VAG406308	Domestic Sewage Discharge	Residence	600
VAG406313	Domestic Sewage Discharge	Residence	450
VAG406314	Domestic Sewage Discharge	Commercial	450
VAG406316	Domestic Sewage Discharge	Residence	300
VAG406322	Domestic Sewage Discharge	Residence	450
VAG406326	Domestic Sewage Discharge	Residence	450
VAG406332	Domestic Sewage Discharge	Residence	600
VAG406333	Domestic Sewage Discharge	Residence	600
VAG406339	Domestic Sewage Discharge	Residence	450
VAG406348	Domestic Sewage Discharge	Residence	600
VAG406278	Domestic Sewage Discharge	Residence	450
VAG406296	Domestic Sewage Discharge	Residence	600
VAG406299	Domestic Sewage Discharge	Residence	300
VAG406327	Domestic Sewage Discharge	Residence	450
VAG406076	Domestic Sewage Discharge	Residence	800
VAG406078	Domestic Sewage Discharge	Residence	400
VAG406094	Domestic Sewage Discharge	Residence	600
VAG406099	Domestic Sewage Discharge	Residence	500
VAG406109	Domestic Sewage Discharge	Commercial	75
VAG406133	Domestic Sewage Discharge	Residence	750
VAG406157	Domestic Sewage Discharge	Residence	600

Table 3-16: Permitted Discharges in the Road Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

Permit No.	Facility Name	Facility Type	Design Flow (GPD)[1]
VAG406209	Domestic Sewage Discharge	Residence	550
VAG406220	Domestic Sewage Discharge	Residence	100
VAG406237	Domestic Sewage Discharge	Residence	600
VAG406242	Domestic Sewage Discharge	Residence	1,000
VAG406248	Domestic Sewage Discharge	Residence	450
VAG406254	Domestic Sewage Discharge	Residence	300
VAG406255	Domestic Sewage Discharge	Residence	450
VAG406256	Domestic Sewage Discharge	Residence	500
VAG406272	Domestic Sewage Discharge	Residence	50
VAG406273	Domestic Sewage Discharge	Residence	600
VAG406280	Domestic Sewage Discharge	Residence	600
VAG406295	Domestic Sewage Discharge	Residence	600
VAG406297	Domestic Sewage Discharge	Residence	600
VAG406298	Domestic Sewage Discharge	Residence	450
VAG406300	Domestic Sewage Discharge	Residence	450
VAG406315	Domestic Sewage Discharge	Residence	450
VAG406319	Domestic Sewage Discharge	Residence	450
VAG406329	Domestic Sewage Discharge	Residence	450
VAG406330	Domestic Sewage Discharge	Residence	600
VAG406057	Domestic Sewage Discharge	Residence	400
VAG406171	Domestic Sewage Discharge	Commercial	500
VAG406202	Domestic Sewage Discharge	Residence	450
VAG406252	Domestic Sewage Discharge	Residence	1,000

1: Source: DEQ

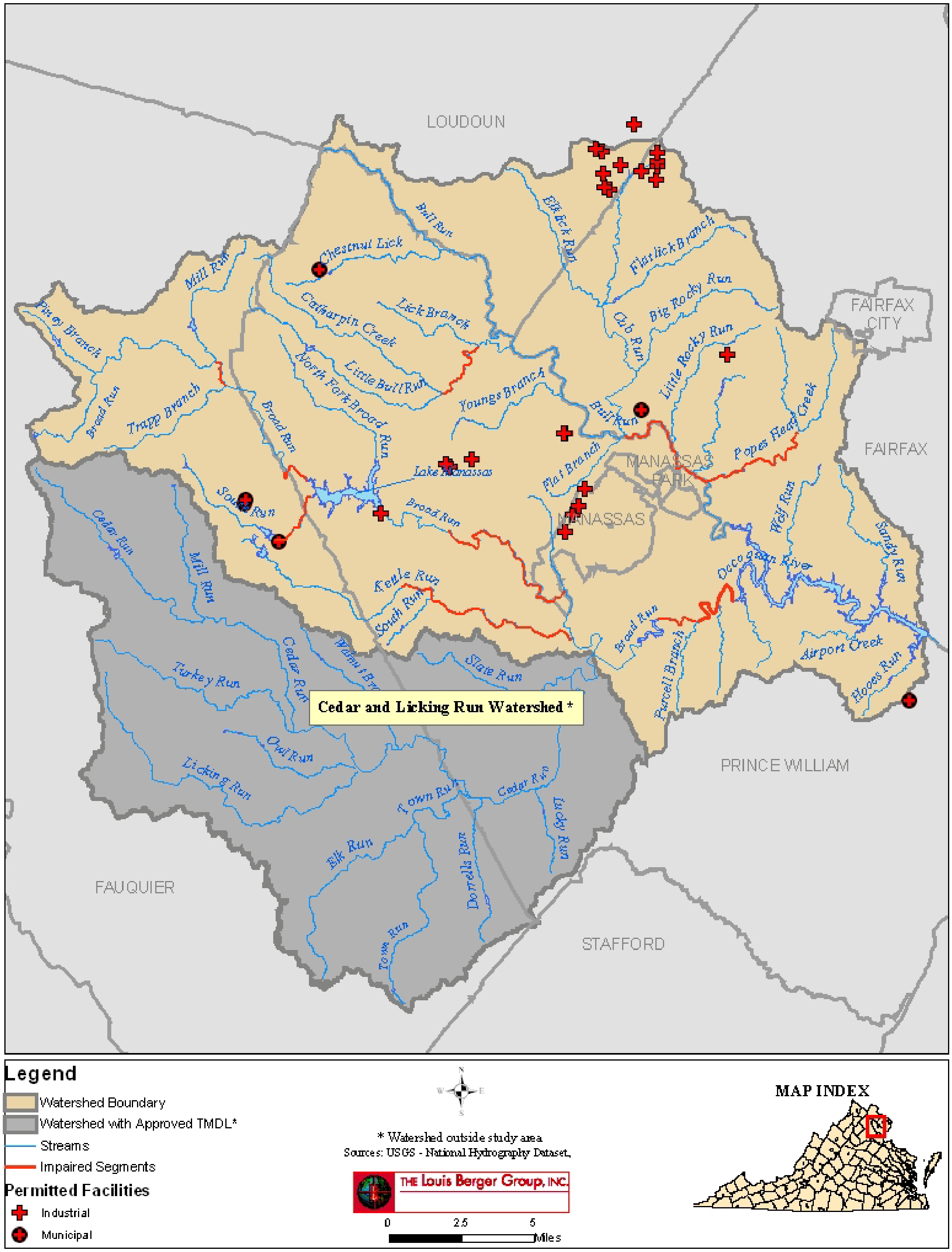

Figure 3-28: Location of Permitted Facilities in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

The available flow data for the permitted facilities was retrieved and analyzed. **Table 3-17** shows the design flow, average flow, permitted bacteria concentration, and average bacteria concentrations recorded for the permitted facilities within the watershed. **Appendix A** shows the average and maximum monthly flows for the facilities for which flow data were available. Average flows for the permitted facilities were used in the HSPF model set-up and calibration.

Fecal coliform data were available only for Vint Hill Farms WWTP, UOSA Centerville, and Woodbridge MHP LLC and were not available for other permitted facilities. The waste treatment plants use chlorine for disinfection, and many measure total contact chlorine as an indication of fecal coliform levels. Total contact chlorine levels for facilities are shown in **Appendix A**. The available data indicate that adequate disinfection was achieved at the plants, and that these facilities were not a large source of fecal coliform loading.

Table 3-17: Inventory and Characterization of Facilities within the Watershed*

Permit No	Facility Name	Facility Type	Design Flow (gpd)	Receiving Stream	Permitted Bacteria Conc. (. cfu/100mL)	Avg. Flow (gpd)*	Ave. Bacteria Conc. (cfu/100mL)
VA0020460	Vint Hill Farms Station WWTP	Mun.	246,000	South Run	200#	84,067	5.1
VA0024988	UOSA - Centreville	Mun.	64,000,000	Bull Run, UT	2#	26,280,921*	<1.0
VA0029092	New Baltimore Shell	Mun.	10,000	Broad Run, UT	N/A	2,851	N/A
VA0050181	Manassas City WTP	Ind.	903,000	Broad Run	N/A	319,816	N/A
VA0051683	Colonial Pipeline - Chantilly	Ind.	440,000	Little Rocky Run, UT	N/A	1,273	N/A
VA0051691	Colonial Pipeline - Bull Run	Ind.	60,000	Bull Run, UT	N/A	612	N/A
VA0064157	Town and Country Restaurant	Mun.	3,800	Broad Run, UT	235✧	3,183	N/A
VA0085901	IBM Corp	Ind.	504,000	Cannon Branch	N/A	66,010	N/A
VA0087700	Atlantic Research Corp - Gainesville	Ind.	14,000,000	Rocky Branch, UT	N/A	916,838	N/A
VA0087858	Sunoco - Manassas Terminal	Ind.	2,215,000	Bull Run, UT	N/A	65,121	N/A

Table 3-17: Inventory and Characterization of Facilities within the Watershed*							
Permit No	Facility Name	Facility Type	Design Flow (gpd)	Receiving Stream	Permitted Bacteria Conc. (. cfu/100mL)	Avg. Flow (gpd)*	Ave. Bacteria Conc. (cfu/100mL)
VA0087891	Evergreen Country Club	Mun.	7,500	Chestnut Lick, UT	N/A	3,304	N/A
VA0088510	Prince William County - Balls Ford Yard Waste	Ind.	192,000	Broar Run UT	N/A	123,684	N/A
VA0089541	MWAA - Washington Dulles Int'l Airport	Ind.	-	Cub Run UT	N/A	2,253,333	N/A
VA0090441	Adaptive Concrete Solutions	Ind.	-	Sand Branch UT	N/A	3,602	N/A
VA0091430	Loudoun Composting	Ind.	-	Sand Branch UT	N/A	141,420	N/A

N/A: Data not available or not applicable
*Based on DMR Data from 1999-2005
Fecal Coliform
✧*E. coli*

3.6.2 Extent of Sanitary Sewer Network

Houses can be connected to a public sanitary sewer, a septic tank, or the sewage can be disposed by other means. Estimates of the total number of households using each type of waste disposal are presented in the next section.

3.6.2.1 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based on two sources of data:

- USGS 7.5 minute quadrangle maps
- U.S. Census Bureau data

The U.S. Census Bureau 2000 data for Fairfax, Fauquier, Loudon, Prince William, Fairfax City, Manassas City, and Manassas Park City, were reviewed to establish the population growth rates in the counties and to validate the housing units' calculation. A summary of the census data and population estimates used for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watershed are presented in **Table 3-18**.

Table 3-18: 2000 Census Data Summary for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watershed

Geography	Total population	Total Housing Units	Total Households
Fairfax	969,749	359,411	350,714
Fauquier	55,139	21,046	19,842
Loudon	169,599	62,160	59,900
Prince William	280,813	98,052	94,570
Fairfax City	21,498	8,204	8,035
Manassas City	35,135	12,114	11,757
Manassas Park City	10,290	3,365	3,254
Total	**1,542,223**	**564,352**	**548,072**

Source: U.S. Census Data, USGS Quad Maps

The 1990 U.S Census Report presents the percent of houses on each sewage disposal type as shown in **Table 3-19**. The 1990 U.S Census Report category "Other Means" includes the houses that dispose of sewage in other ways than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewer directly via straight pipes if located within 200 feet of a stream.

Table 3-19: Percent of Houses within Each County on Public Sewers, Septic Systems, and Other Means

County	% Public Sewer	% Septic Tank	% Other Means
Fairfax	93	6.4	~0
Fauquier	27	71	~0
Loudon	74	25	~0
Prince William	84	16	~0
Fairfax City	99	1	~0
Manassas City	99	1	~0
Manassas Park City	100	0	0

Source: U.S. Census Data

3.6.2.2 Failed Septic Systems

In order to determine the amount of fecal coliform contributed by human sources, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rate was assumed to be 3 percent of the total septic systems in the watershed. In order to determine the load of bacteria from these sources, it was assumed that the septic system design flow is 75 gallons per person per day (based on previous studies and TMDLs). In addition, it was estimated that typical fecal coliform concentrations from a failed septic system is 10,000 cfu/100mL and from a straight pipe is 1,040,000 cfu/100 mL (Tinker Creek TMDL Report, 2004). **Table 3-20** shows the estimates of the population on septic systems and straight pipes, the amount of failing systems, and the flow and fecal coliform load produced daily.

Table 3-20:Estimates of the Number of Septic Systems and Straight Pipes in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds

Category	# of People on system	# People per Household	# Failing Systems	People Served	Flow (gal/day)	Daily Load (#cfu/day)
Septic Systems	36,800	2.88	383.1	1,104	82,800	3.13E+10
Straight Pipes	48	2.87	16.8	48	3,612	1.42E+11

3.6.3 Livestock

An inventory of the livestock residing in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds was conducted using data and information provided by United States Department of Agriculture (USDA) National Agricultural Statistics Service, Virginia's Department of Conservation and Recreation, NRCS, Virginia Agricultural Statistics Service (2002),the 2001 Virginia Equine Report, Soil and Water Conservation Districts (SWCD), as well as field surveys. **Table 3-21** summarizes the livestock inventory in the watershed. Livestock invetories are shown in **Appendix B.**

Table 3-21: Livestock Inventory	
Livestock Type	**Number of Animals**
Beef cows	4,307
Milk cows	1,180
Hogs and pigs	34
Sheep and lambs	127
Layers 20 weeks old and older	430
Horses and ponies	4,896
Alpacas	270

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. **Table 3-22** shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-22: Daily Fecal Coliform Production of Livestock		
Livestock Type	**Daily Fecal Coliform Production (millions of cfu/day)**	**Reference**
Cattle and calves	5,400	Metcalf and Eddy, 1991
Beef Cows	100,000	ASAE, 1998
Dairy Cows	100,000	ASAE, 1998
Hogs & Pigs	8,900	Metcalf and Eddy, 1991
	11,000	ASAE, 1998
Sheep & Lambs	18,000	Metcalf and Eddy, 1991
	12,000	ASAE, 1998
Horses & Ponies	420	ASAE, 1998
Apacas	12,960	Maptech, 2006

Source: USEPA Protocol for Developing Pathogen TMDLs, 2001

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds, the initial estimates of the beef cattle daily schedule were based on the Dodd Creek TMDL. The amount of time beef cattle spend in the pasture and stream was also presented during the TAC meetings where local stakeholders provided comments. The monthly schedule was adjusted to reflect the conditions in the watershed.

The daily schedule for beef cattle that was accepted by the stakeholders is presented in **Table 3-23**. The daily schedule for dairy cows that was accepted by the stakeholders is presented in **Table 3-24**. The time beef cattle and dairy cows spend in the pasture or loafing was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from livestock was based on the amount of time they spend in the stream.

Table 3-23: Daily Schedule for Beef Cattle

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Dodd Creek TMDL Report, DCR 2002.

Table 3-24: Daily Schedule for Dairy Cows

Month	Time Spent in		
	Pasture	Stream	Loafing Lot
	(Hour)	(Hour)	(Hour)
January	7.45	0.25	16.30
February	7.45	0.25	16.30
March	8.10	0.50	15.40
April	9.35	0.75	13.90
May	10.05	0.75	13.20
June	10.30	1.00	12.70
July	10.80	1.00	12.20
August	10.80	1.00	12.20
September	11.05	0.75	12.20
October	11.00	0.50	12.50
November	10.30	0.50	13.20
December	9.15	0.25	14.60

Source: Dodd Creek TMDL Report, DCR 2002.

3.6.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Both dairy operations and beef cattle are present in the watershed. Because there are no recorded feedlots, or a significant number of manure storage facilities present in the watershed, the manure produced by confined livestock was directly applied on the pasturelands, and was treated as an indirect source in the development of the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River TMDLs.

3.6.5 Land Application of Biosolids

Non-point human sources of fecal coliform can be associated with the spreading of biosolids. Data provided by Virginia Department of Health (VDH) indicated that there has been some biosolids land application in Fauquier and Loudon Counties and no spreading of biosolids in Prince William County. Recorded biosolid application conducted in 2003 and 2004 is presented in **Table 3-25**.

Table 3-25: Biosolid Application by County (dry ton/year) *				
Year	Fairfax	Fauquier	Loudon	Prince William
2003	-	7,143	7,572	0
2004	-	10,014	3,478	0

* Source: VDH

3.6.6 Wildlife

Similar to livestock contributions, wildlife contributions of fecal coliform can be both indirect and direct. Indirect sources are those that are carried to the stream from the surrounding land via rain and runoff events, whereas direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

A wildlife inventory was conducted based on habitat availability within the watershed. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in **Table 3-26.**

Table 3-26: Wildlife Densities		
Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	Within 66 feet of streams and ponds
Goose	0.02 animals/acre*	Entire Watershed
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding urban land uses
Source: Map Tech, Inc., 2001, *Source: Goose Creek TMDL, 2004; Catoctin Creek TMDL, 2004		

The wildlife inventory presented in **Table 3-27** was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval. Wildlife inventories by subwatershed are shown in **Appendix B**.

Table 3-27: Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River Watersheds Wildlife Inventory

Wildlife Type	Number
Deer	11,908
Raccoon	10,255
Muskrat	44,316
Beaver	4,834
Goose	5,067
Mallard	507
Wood Duck	29
Wild Turkey	1,695

The wildlife inventory was used to determine the fecal coliform loading by wildlife within the watershed. **Table 3-28** shows the average fecal coliform production per animal, per day, contributed by each type of wildlife. Separation of the wildlife daily fecal coliform load into direct and indirect deposits was based on estimates of the amount of time each type of wildlife spends on land versus time spent in the stream. **Table 3-28** also shows the percent of time each type of wildlife spends in the stream on a daily basis.

Table 3-28: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.6.7 Pets

The contribution of fecal coliform loading from pets was also examined in the assessment of fecal coliform loading to Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River. The two types of domestic pets that were considered as sources of bacteria in this TMDL were cats and dogs. The number of pets residing in the watershed was estimated by determining the number of households in the watershed, and multiplying this number by national average estimates of the number of pets per household as 0.543 dogs per household and 0.593 cats per household (AVMA, 2005, and Catoctin Creek TMDL, 2002). Based on these estimates, approximately 62,450 dogs and 68,800 cats were estimated to reside within the watershed.

Fecal coliform loading from pets occurs primarily in residential areas. The load was estimated based on daily fecal coliform production rate of 5.04 $x10^2$ cfu/day per cat and 4.09 $x10^9$ cfu/day per dog.

4.0 Modeling Approach

This section describes the modeling approach used in the TMDL development. The primary focus is on the sources represented in the model, assumptions used, model set-up, calibration, and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the water body that can:

- represent the watershed characteristics
- represent the point and nonpoint sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the in-stream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the in-stream conditions and the water quality standard

4.2 Watershed Boundaries

The nine impaired segments are located in the Occoquan River Basin (USGS Cataloging Unit 02070010). The Occoquan River flows through Prince William and Fairfax Counties. Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, and Bull Run are tributaries to the Occoquan River and flow through Fauquier, Loudon, Prince William, Fairfax Counties and Manassas, Manassas Park and Fairfax Cities. The watershed that encompasses the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River bacteria impairments is approximately 253,350 acres. **Figure 4-1** shows the boundaries of the watershed that encompasses the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River.

Figure 4-1: Watershed Boundary

4.3 Modeling Strategy

4.3.1 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used to predict the in-stream water quality conditions under varying scenarios of rainfall and fecal coliform loading. The results from the developed model are subsequently used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Consequently, HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineate the watershed into smaller subwatersheds
- enter the physical data that describe each subwatershed and stream segment
- enter values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the next sections.

4.3.2 Modeling Approach – Boundary Conditions

As mentioned in Section 3.2, bacteria TMDLs have already been approved for two of the impaired streams within the watershed. Both Cedar and Licking Run were impaired for bacteria and flow into the Occoquan River.

The TMDLs developed in this study will incorporate the results of the bacteria TMDLs developed for the Cedar and Licking Run watershed. Since time series data were available for Cedar and Licking Runs, this watershed model will be used as is and as a boundary condition to the HSPF model simulating hydrology and water quality in the study area. **Table 4-1** depicts the hydrology and water quality sources used at each of the boundary conditions.

Table 4-1: Sources for Boundary Conditions

Boundary Watershed	Hydrology Data	Water Quality Data
Cedar and Licking Run	USGS Gauge 01644000	Fecal Loads from Cedar and Licking Run TMDL

4.4 Watershed Delineation

For this TMDL, the river watershed was delineated into 52 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. Size distributions of the 52 subwatersheds are presented in **Table 4-2. Figure 4-2** is a map showing the delineated subwatersheds for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds.

Table 4-2: Subwatersheds Delineation

Sub-watershed	Drainage Area (acres)	Sub-watershed	Drainage Area (acres)
1	22,412	27	3,533
2	2,694	28	5,199
3	2,964	29	3,953
4	365	30	5,739
5	1,133	31	1,250
6	3,622	32	6,561
7	7,382	33	1,908
8	11,547	34	4,945
9	898	35	5,697
10	265	36	4,297
11	1,668	37	5,392
12	414	38	4,203
13	5,991	39	514
14	2,987	40	1,079
15	14,905	41	7,705
16	7,399	42	443
17	16,677	43	5,031
18	7,393	44	12,606
19	1,794	45	6,073
20	7,119	46	23
21	7,489	47	1,165
22	3,488	48	3,124
23	1,134	49	596
24	1,176	50	1,216
25	6,133	51	7,910
26	5,636	52	6,888
Subtotal Acreage	146,274	**Subtotal Acreage**	107,080
Acreage Grand Total	**253,354**		

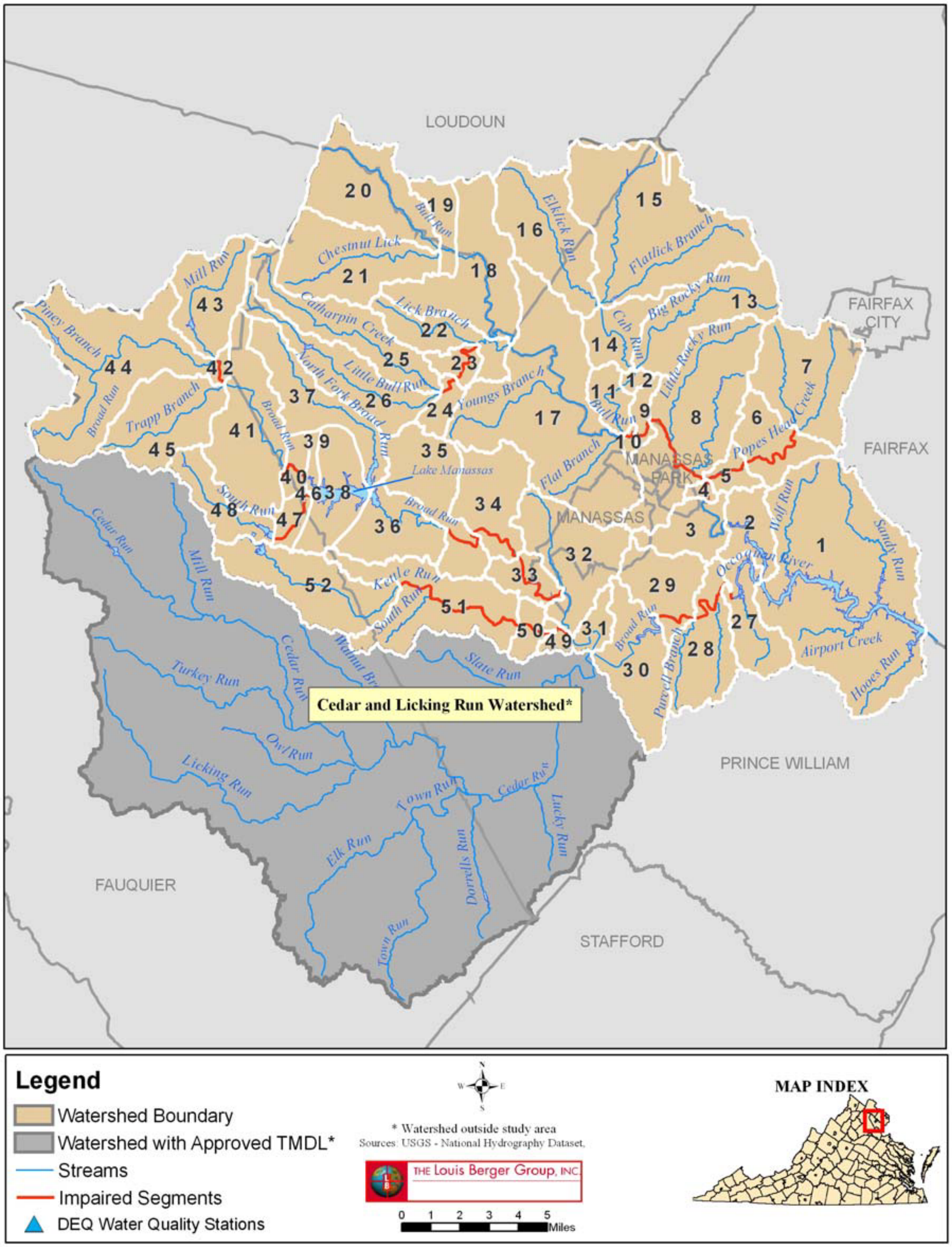

Figure 4-2: Modeled Subwatersheds

4.5 Land Use Reclassification

As previously mentioned, land use distribution in the study area was determined using USGS NLCD and NVRC data. The land use data and distribution of land uses were presented in Chapter 3. There are 14 land use classes present in the watershed; the dominant land uses are forested and agricultural land uses. The original 14 land use types were consolidated into 8 land use categories to meet modeling goals, facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 14 land use types to a representative number of categories that best describe conditions and the dominant fecal coliform source categories in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds. Land use reclassification was based on similarities in hydrologic characteristics and potential fecal coliform production characteristics. The reclassified land uses are presented in **Tables 4-3** through **4-10** for the impaired Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run, and the Occoquan River watersheds respectively.

Table 4-3: Broad Run (Segment VAN-A19R-01) Land Use Reclassification

Land Use Category	Acres	Percent
Commercial/Industrial	2,349.09	8.7%
Cropland	2,234.17	8.3%
Forest	11,025.61	40.9%
High Residential	1,574.34	5.8%
Low Residential	2,184.7	8.1%
Other Urban	1,105.55	4.1%
Pasture	5,837.31	21.6%
Water/Wetland	669.88	2.5%
Grand Total	26,980.65	100.0%

Table 4-4: Broad Run (Segment VAN-A19R-02) Land Use Reclassification

Land Use Category	Acres	Percent
Commercial/Industrial	449.8	1.4%
Cropland	3,212.78	9.8%
Forest	14,802.69	44.9%
High Residential	0.0	0.0%
Low Residential	1,546.27	4.7%
Other Urban	37.71	0.1%
Pasture	12,856.72	39.0%
Water/Wetland	34.31	0.1%
Grand Total	32,940.28	100.0%

Table 4-5: Bull Run (Segment VAN-A23R-01) Land Use Reclassification		
Land Use Category	Acres	Percent
Commercial/Industrial	10,132.14	11.0%
Cropland	6,420.53	7.0%
Forest	29,573.76	32.2%
High Residential	14,449.37	15.7%
Low Residential	10,083.04	11.0%
Other Urban	5,364.91	5.8%
Pasture	14,680.66	16.0%
Water/Wetland	1,279.05	1.4%
Grand Total	91,983.46	100.0%

Table 4-6: Kettle Run (Segment VAN-A19R-03) Land Use Reclassification		
Land Use Category	Acres	Percent
Commercial/Industrial	144.47	0.9%
Cropland	3,976.15	23.9%
Forest	5,863.88	35.3%
High Residential	39.75	0.2%
Low Residential	2,354.11	14.2%
Other Urban	213.31	1.3%
Pasture	3,958.6	23.8%
Water/Wetland	61.96	0.4%
Grand Total	16,612.23	100.0%

Table 4-7: Little Bull Run (Segment VAN-A21R-01) Land Use Reclassification		
Land Use Category	Acres	Percent
Commercial/Industrial	311.48	2.2%
Cropland	1,020.11	7.2%
Forest	7,453.76	52.9%
High Residential	380.64	2.7%
Low Residential	958.87	6.8%
Other Urban	618.62	4.4%
Pasture	3,287.89	23.4%
Water/Wetland	49.48	0.4%
Grand Total	14,080.85	100.0%

Table 4-8: Occoquan River (Segment VAN-A20R-01) Land Use Reclassification		
Land Use Category	Acres	Percent
Commercial/Industrial	1,406.73	8.0%
Cropland	1,006.72	5.8%
Forest	5,548.78	31.7%
High Residential	1,842.79	10.5%
Low Residential	5,469.5	31.2%
Other Urban	832.12	4.8%
Pasture	1,257.84	7.2%
Water/Wetland	140.5	0.8%
Grand Total	17,504.98	100.0%

Table 4-9: Popes Head Creek (Segment VAN-A23R-02) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
Commercial/Industrial	286.91	2.4%
Cropland	11.53	0.1%
Forest	4,431.03	36.5%
High Residential	1,407.49	11.6%
Low Residential	5,076.25	41.8%
Other Urban	394.35	3.2%
Pasture	374.23	3.1%
Water/Wetland	157.39	1.3%
Grand Total	12,139.18	100.0%

Table 4-10: South Run (Segment VAN-A19R-04) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
Commercial/Industrial	99.07	2.3%
Cropland	58.32	1.4%
Forest	1,509.09	35.2%
High Residential	3.41	0.1%
Low Residential	1,245.66	29.0%
Other Urban	8.74	0.2%
Pasture	1,285.24	30.0%
Water/Wetland	79.76	1.9%
Grand Total	4,289.29	100.0%

4.6 Hydrographic Data

Hydrographic data describing the stream network were obtained from the National Hydrography Dataset (NHD) and the Reach File Version 3 (RF3) dataset contained in BASINS. These data were used for HSPF model development and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River are included in the RF3 database.

The stream geometry was field surveyed for representative reaches of Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River. The Occoquan River and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient. Model representation of the Broad Run, Kettle Run, South

Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River stream reach segments is presented in Appendix C.

4.7 Fecal Coliform Sources Representation

This section demonstrates how the fecal coliform sources identified in Chapter 3 were included or represented in the model. These sources include permitted sources, human sources (failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids.

4.7.1 Permitted Facilities

There are 15 individually permitted facilities and 67 domestic sewage general permits located in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed. Out of the 15 individually permitted facilities located within the watershed, 3 have permitted limits for bacteria. The permit number, design flow, and status for each facility were presented in **Table 3-16**.

For TMDL development, average discharge flow values were considered representative of flow conditions at each permitted facility, and were used in HSPF model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

4.7.2 Failed Septic Systems

Failed septic system loading to Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River can be direct (point) or land-based (indirect or nonpoint), depending on the proximity of the septic system to the stream. In cases where the septic system is within the 200 foot stream buffer, the failed septic system was represented in the model as a constant source (similar to a permitted facility). As explained in Chapter 3, the total number of septic systems in the watershed was estimated at 12,768 systems. Based on GIS data, only 2,982 out of the 12,768 households on septic systems were located within the 200 foot stream buffer. Therefore, the failed septic system load was considered a land-based load in the watershed.

For TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of conditions in the watershed. This corresponds to a total of 383 failed septic systems in the study area. To account for uncontrolled discharges in the watershed and failed septic systems within the stream buffer, a total of 17 straight pipes were included in the model. This estimate was based on field observations, discussions with DCR and DEQ, stakeholder comments, evaluation of the BST results, and 1990 Census data.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems' design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100mL were used in the fecal coliform load calculations. Fecal coliform loading from failed septic systems that are not within the 200 ft buffer of the stream is considered to be a predominantly indirect source. Failed septic systems within the stream buffer and straight pipes were represented as constant sources of fecal coliform. **Table 4-11** shows the distribution of the septic systems and straight pipes in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed.

Table 4-11: Failed Septic Systems and Straight Pipes Assumed in Model Development

Sub-watershed ID	# of Septic Systems	# of Failed Septic Systems	# of Straight Pipes	Sub-watershed ID	# of Septic Systems	# of Failed Septic Systems	# of Straight Pipes
1	2,511	75	1	**27**	131	4	0
2	41	1	0	**28**	236	7	0
3	89	3	0	**29**	152	5	0
4	6	0	0	**30**	165	5	1
5	9	0	0	**31**	66	2	0
6	47	1	0	**32**	236	7	0
7	296	9	0	**33**	35	1	0
8	879	26	1	**34**	273	8	0
9	86	3	0	**35**	146	4	0
10	75	2	0	**36**	118	4	0
11	112	3	0	**37**	73	2	0
12	28	1	0	**38**	127	4	0
13	823	25	0	**39**	9	0	0
14	195	6	0	**40**	29	1	0
15	773	23	0	**41**	486	15	1
16	178	5	1	**42**	7	0	0
17	1,921	58	1	**43**	80	2	0
18	140	4	1	**44**	200	6	2
19	34	1	0	**45**	315	9	0
20	103	3	1	**46**	1	0	0
21	99	3	0	**47**	90	3	0
22	53	2	0	**48**	338	10	2
23	17	1	0	**49**	8	0	0
24	22	1	0	**50**	16	0	0
25	84	3	0	**51**	206	6	0
26	77	2	0	**52**	531	16	1

Total	**12,768**	**383**	**17**

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in **Figure 4-3**. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, land-based fecal coliform deposited by livestock while grazing.

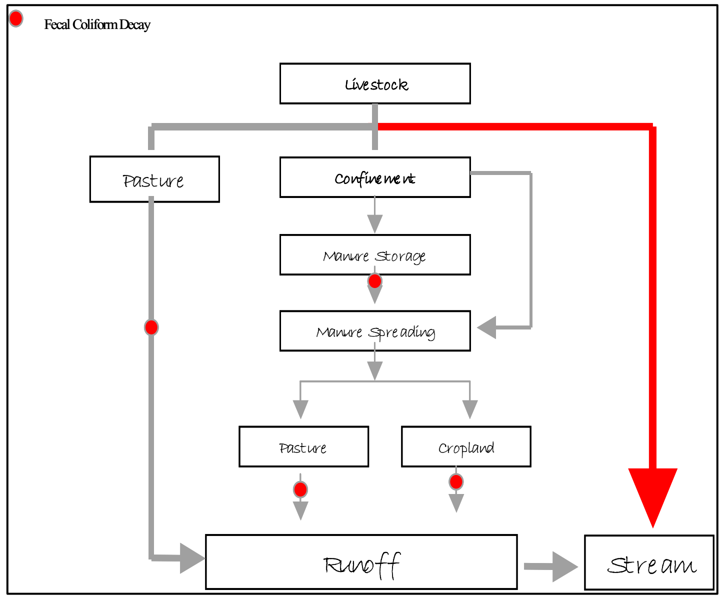

Figure 4-3: Livestock Contribution to Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River

Based on the inventory of livestock in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed, it was determined that beef cattle and horses are the predominant type of livestock, though dairy cows, goats, sheep, alpacas, hogs and pigs, chickens, are also present in the watershed. The inventory indicated that there are no feedlots in the watershed.

The distribution of the daily fecal coliform load between direct in-stream and indirect (land-based) loading was based on livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream. The amount of time livestock spend in the stream was presented in Chapter 3.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix D.

4.7.4 Land Application of Manure

Beef cattle, as well as several dairy operations, are present in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed. Because there are no feedlots or large manure storage facilities present in the watershed, the daily produced manure is applied to pastureland in the watershed, and was treated as an indirect source in the development of the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River TMDL. Beef cattle spend the majority of their time on pastureland and are not confined. Thus, fecal coliform loading from beef cattle was accounted for via the methods described above. Dairy cattle do spend time in confinement, and their fecal coliform load was included in the calculation of land application of manure. Fecal coliform loading from land application of manure was estimated based on the total number of dairy cows in the watershed, the fecal coliform production per animal per day, and the percent of time dairy cows were in confinement.

4.7.5 Land Application of Biosolids

Biosolids application in the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds was considered under this TMDL development. Biosolids were modeled as land based loads applied to crop and pasture lands in each watershed. The loads modeled were based on county specific annual application estimates reported by the Virginia Department of Health.

4.7.6 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on estimates of the amount of time each type of wildlife spends on the surrounding land versus in the stream.

Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 3). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed. The resulting fecal coliform load was then distributed to forest and pasture land uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed.

4.7.7 Pets

For the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River TMDLs, pet fecal coliform loading was considered a land-based load that was primarily deposited in urban land within the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per type of pet.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

In the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River TMDL, in-storage die-off was not included in the model because there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

4.9.1 Model Set-Up

4.9.1.1 Stream Flow Data

The HSPF model was set up and calibrated based on flow data taken by the Occoquan Watershed Monitoring Lab at Station 45 (ST45). This station was selected because of its unrestricted flow within the watershed. Average flow data for the period of 1995 to 2003 for this station is plotted in **Figure 4-4.**

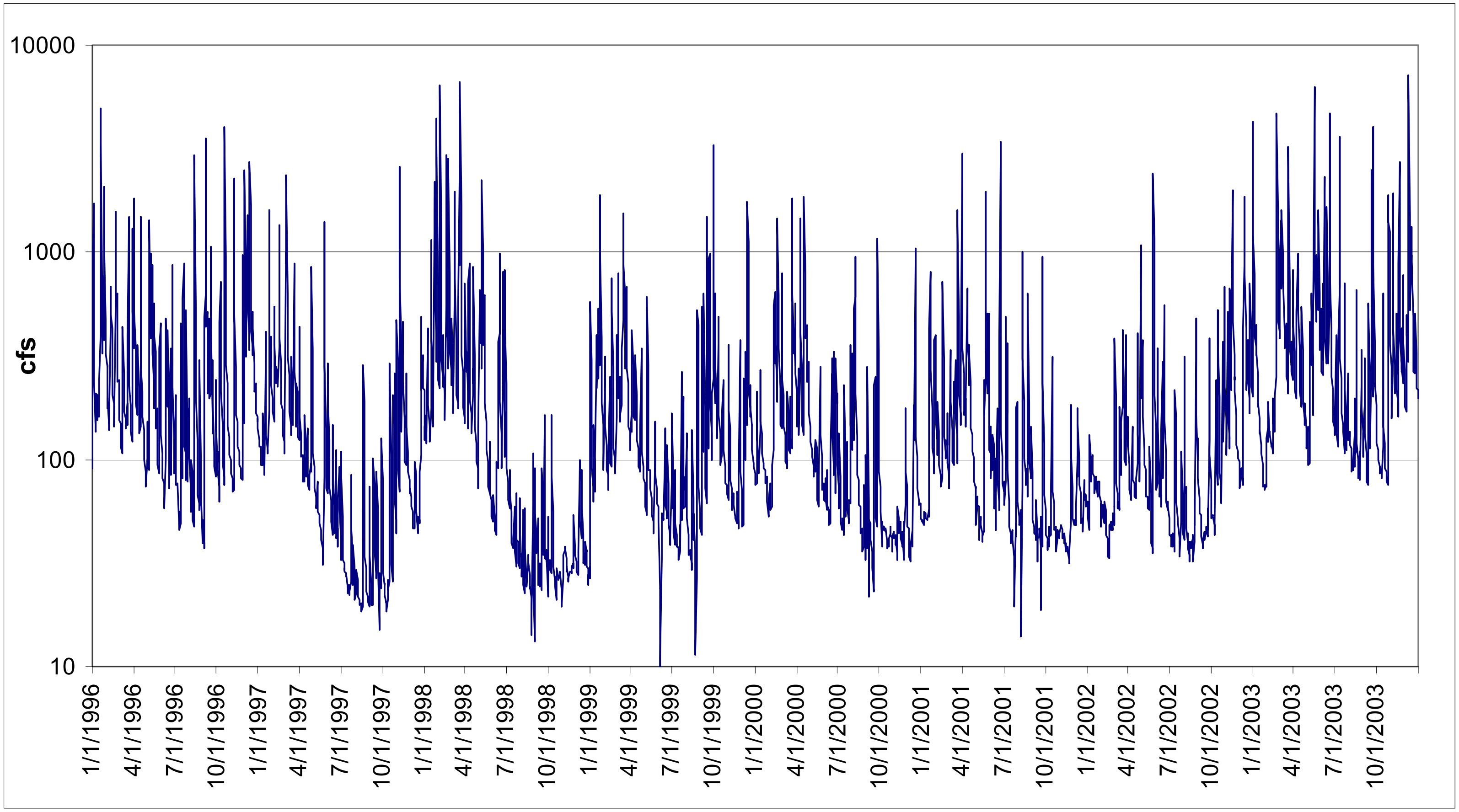

Figure 4-4: Flow Data at OWML Station ST45

A 4-year period (1996-1999) was selected as the calibration period for the hydrologic model. The validation period selected spans from 2000 to 2003.

4.9.1.2 Rainfall and Climate Data

Hourly precipitation data for the Occoquan Watershed Monitoring Laboratory (OWML) was used in the hydrological modeling. Surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation) were obtained from the NCDC Dulles Airport Station.

4.9.2 Model Hydrologic Calibration Results

HSPEXP software was used to calibrate the hydrology of the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watershed. After each model's iteration, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the hydrologic model was calibrated from January 1996 to December 1999 at the OWML flow station. Calibration results are presented in **Table 4-12**, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is presented in **Table 4-13**. The model results and the observed daily average flow at the calibration station are plotted in **Figure 4-5**.

Table 4-12: OWML ST45 Model Calibration Results

Category	Simulated	Observed
Total runoff, in inches	88.94	90.55
Total of highest 10% flows, in inches	44.05	46.36
Total of lowest 50% flows, in inches	11.15	10.57
Total storm volume, in inches	15.36	19.56
Average of storm peaks, in cfs	3140.2	2800.8
Baseflow recession rate	0.940	0.930

Table 4-12: OWML ST45 Model Calibration Results		
Category	Simulated	Observed
Summer flow volume, in inches	15.64	9.98
Winter flow volume, in inches	29.33	34.83
Summer storm volume, in inches	0.58	0.78

Table 4-13: OWML ST45 Model Calibration Error Statistics		
Category	Current	Criterion
Error in total volume	-1.8	± 10.000
Error in low flow recession	-0.01	± 0.01
Error in 50% lowest flows	5.5	± 10.000
Error in 10% highest Flow	-5.0	± 15.000
Error in Storm Peaks	12.1	± 15.000
Summer Storm Volume Error	-4.8	± 15.000

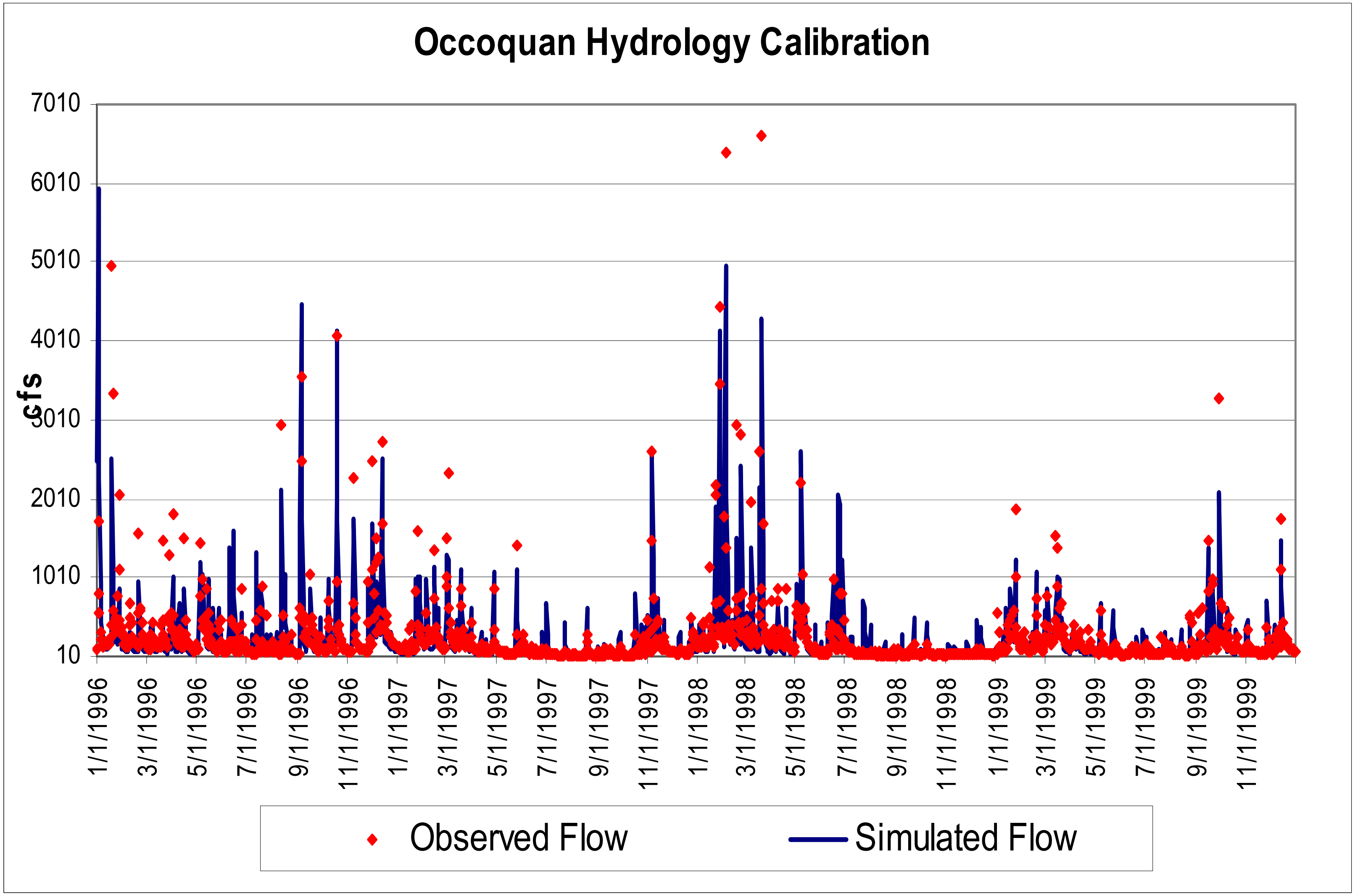

Figure 4-5: OWML Station 45 Model Hydrologic Calibration Results

4.9.3 Model Hydrologic Validation Results

The period of January 2000 to December 2003 was used to validate the HSPF model. Model validation results at the OWML Station 45 (ST45) are presented in **Table 4-14**, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is also presented for this station in **Table 4-15**. The error statistics indicate that the validation results were within the recommended ranges in HSPF. The model's hydrology validation results are plotted in **Figure 4-6**.

Table 4-14: OWML ST45 Model Calibration Results Model Validation Results

Category	Simulated	Observed
Total runoff, in inches	85.37	87.67
Total of highest 10% flows, in inches	42.76	44.39
Total of lowest 50% flows, in inches	10.78	11.3
Total storm volume, in inches	12.64	18.07
Average of storm peaks, in cfs	2,994.1	2606.9
Baseflow recession rate	0.930	0.940
Summer flow volume, in inches	16.98	17.85
Winter flow volume, in inches	23.73	22.69
Summer storm volume, in inches	3.900	5.354

Table 4-15: OWML ST45 Model Calibration Results Model Validation Error Statistics

Category	Current	Criterion
Error in total volume	-2.6	$\pm$ 10.000
Error in low flow recession	0.01	$\pm$ 0.01
Error in 50% lowest flows	-4.6	$\pm$ 10.000
Error in 10% highest Flow	-3.7	$\pm$ 15.000
Error in Storm Peaks	14.9	$\pm$ 15.000
Summer Storm Volume Error	2.90	$\pm$ 15.000

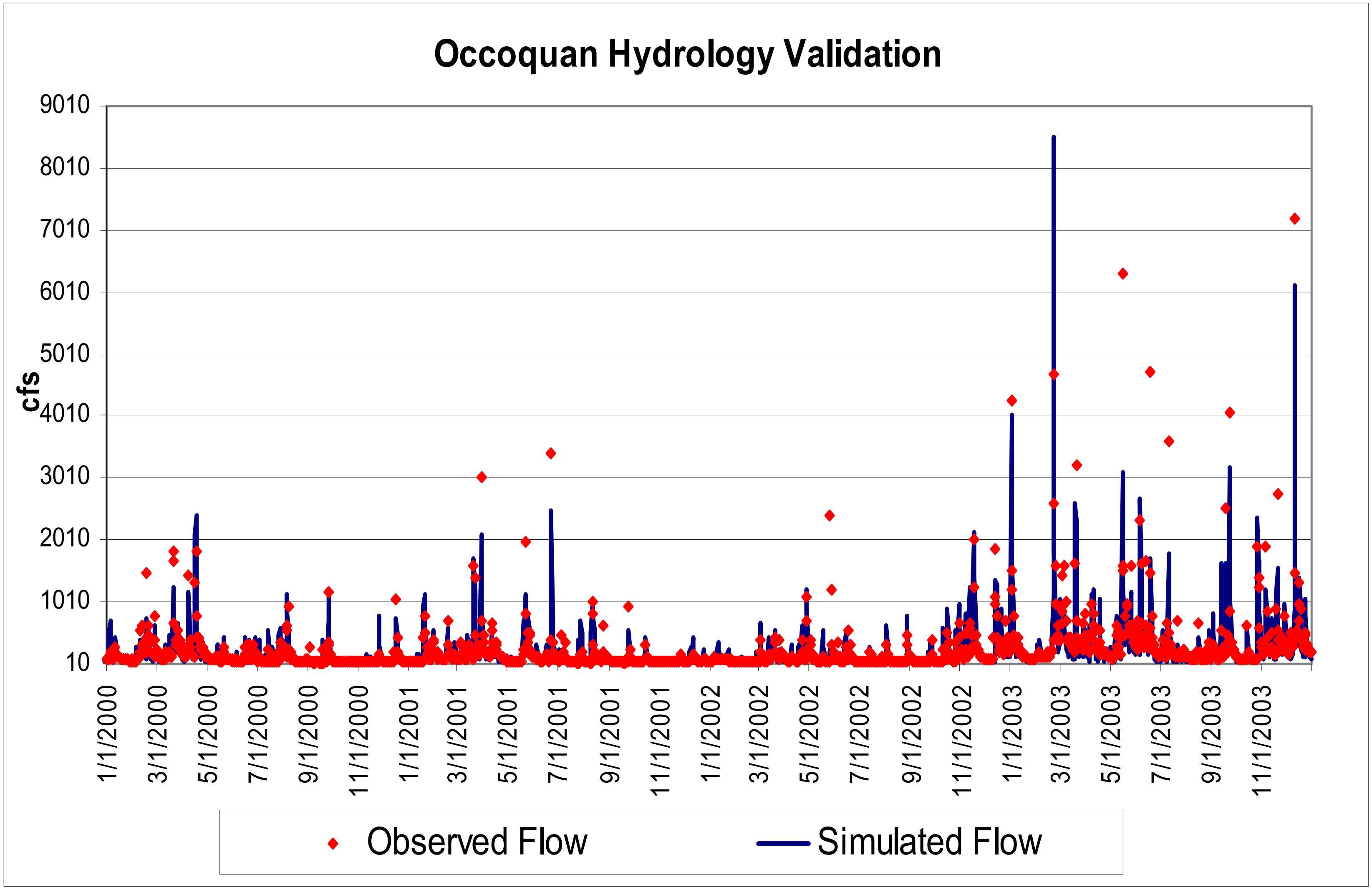

Figure 4-6: OWML Station 45 (Bull Run) Model Hydrologic Validation Results

There is good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. Model results closely match the observed flows during low flow conditions, base flow recession, and storm peaks. The final parameter values of the calibrated model are listed in **Table 4-16**.

Table 4-16: Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River HSPF Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	1.0	0.0-1.0
LZSN	Lower zone nominal soils moisture	inch	3	8	0.01	100	6
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.0001	100	0.07-0.09
LSUR	Length of overland flow	Ft	200	500	1	None	250-300
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.00001	10	0.0949 - 0.0986
KVARY	Groundwater recession variable	1/inch	0	3	0	None	0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.001	0.999	0.30 - 0.35
PETMAX	Air temp below which ET is reduced	Deg F	35	45	None	None	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	None	None	35
INFEXP	Exponent in infiltration equation	None	2	2	0	10	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	2	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	1.0	0.01
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	1.0	0.01

Parameter	Definition	Units	Typical		Possible		Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River
			Min	Max	Min	Max	
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	1.0	0
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.00	10.0	0.05-0.15
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.01	10.0	0.7
NSUR	Manning's n	None	0.15	0.35	0.001	1.0	0.25
INTFW	Interflow/surface runoff partition parameter	None	1	3	0	None	1.7
IRC	Interflow recession parameter	None	0.5	0.7	0.001	0.999	0.25
LZETP	Lower zone ET parameter	None	0.2	0.7	0.0	0.999	0.1 - 0.89
RETSC*	Retention storage capacity of the surface	inch					0.065
ACQOP*	Rate of accumulation of constituent	#/ac day					2.50E7 - 3.52E9
SQOLIM*	Maximum accumulation of constituent	#					4.5E7 - 6.34E9
WSQOP*	Wash-off rate	Inch/hour					0.7-1.2
IOQC*	Constituent concentration in interflow	#/CF					1416
AOQC*	Constituent concentration in active groundwater	#/CF					283
KS*	Weighing factor for hydraulic routing		0.5				0.5
FSTDEC*	First order decay rate of the constituent	1/day	1.152 (FC)				1.152
THFST*	Temperature correction coefficient for FSTDEC	none	1.07				1.07

*Typical values these parameters are unavailable because they are site-specific and determined through model calibration.

4.9.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available in-stream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. In Chapter 3, in-stream monitoring stations on the impaired segments were listed and sampling events conducted on Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River were summarized and presented. **Table 4-17** lists the stations used in the water quality calibration for each impaired segment.

Table 4-17: Water Quality Station used in the HSPF Fecal Coliform Simulations

Watershed	Water Quality Station	HSPF Model Segment
Popes Head Creek	1APOE002.00	05
Bull Run	1ABUL010.28	04
Little Bull Run	1ALII003.97	23
Occoquan River	1AOCC024.74	28
Broad Run	1ABRU007.58	34
Broad Run	1ABRU020.12	40
South Run	1ASOT001.44	47
Kettle Run	1AKET000.80	50

The period used for water quality calibration of the model, and the period used for model validation depended on the time the water quality observations were collected. It is important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values.

A total of 9 TMDLs were developed for this report and for clarity reasons only a sample of water quality simulations is shown in **Figure 4-7** and **Figure 4-8**, which depict the simulated water quality at Popes Head Creek. All the water quality plots are presented in Appendix D for each station and summarized in **Table 4-18**.

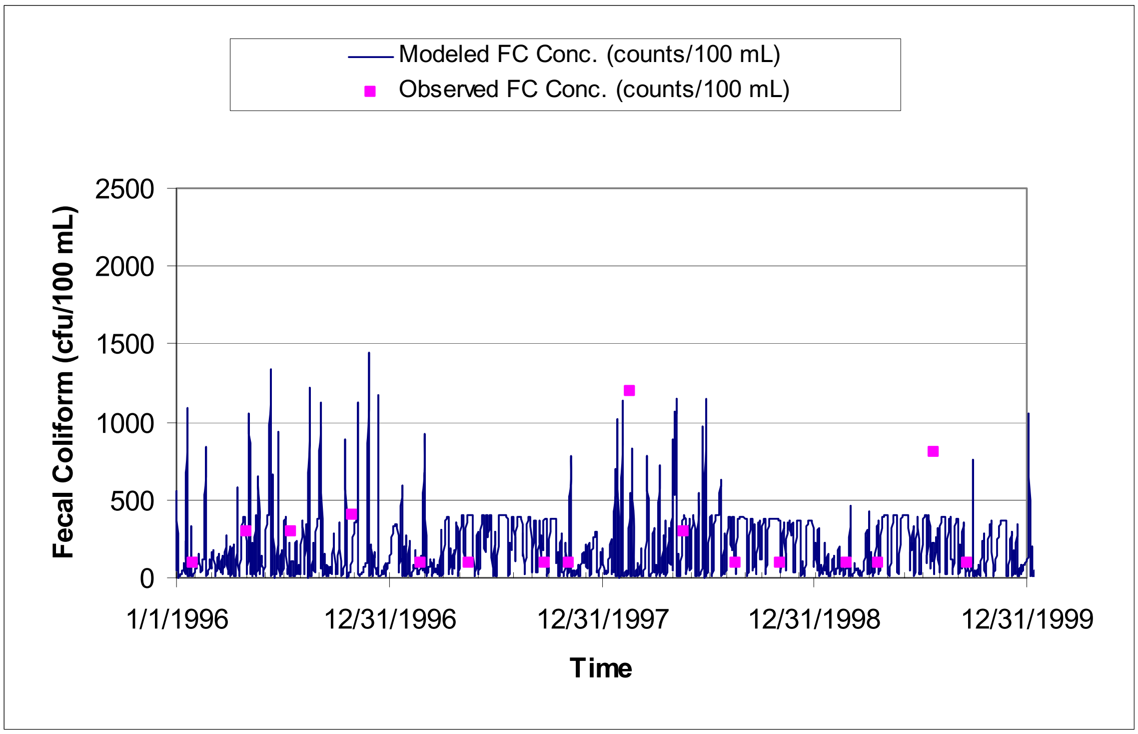

Figure 4-7: Fecal Coliform Calibration Popes Head Creek (Reach 5)

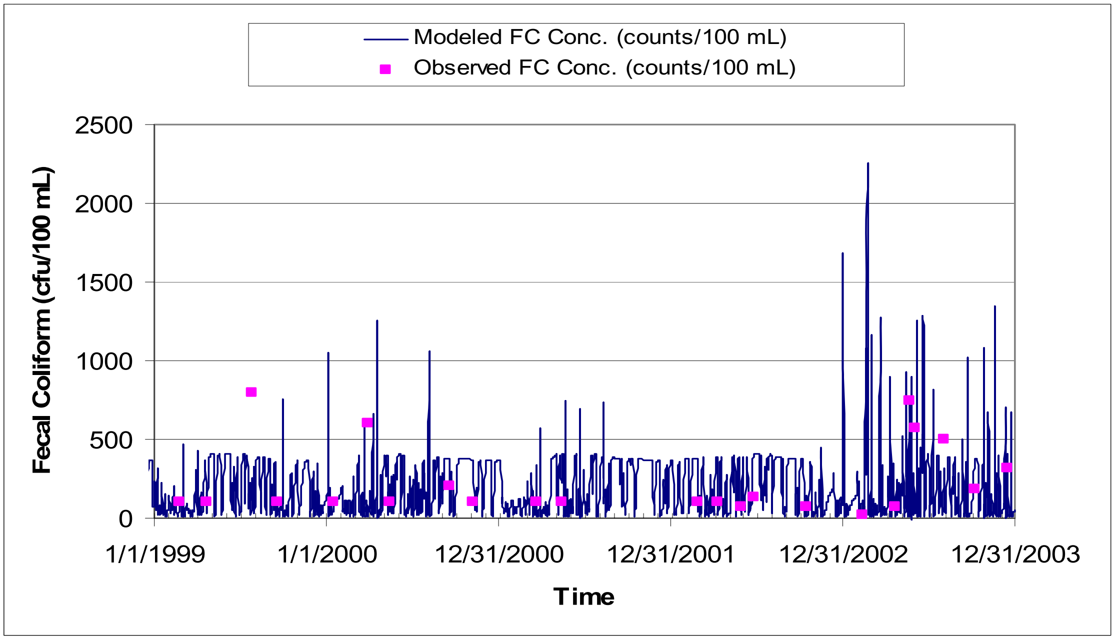

Figure 4-8: Fecal Coliform Validation Popes Head Creek (Reach 5)

The goodness of fit for the water quality calibration was evaluated visually. Analysis of the model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and thus was well-calibrated. **Table 4-18** shows the observed and simulated geometric mean fecal coliform concentration spanning the period from 2000 to 2004. **Table 4-19** shows the observed and simulated exceedance rates of the 400 cfu/100 ml instantaneous fecal coliform standard.

Table 4-18: Observed and Simulated Geometric Mean Fecal Coliform Concentration 2000-2004

Station	Reach	Geometric Mean	
		Simulated	Observed
1APOE002.00	Popes Head Creek	90	131
1ABUL010.28	Bull Run	105	144
1ALII003.97	Little Bull Run	130	139
1AOCC024.74	Occoquan River	149	201
1ABRU007.58	Broad Run - 34	208	224
1ABRU020.12	Broad Run - 40	278	251
1ASOT001.44	South Run	142	195
1AKET000.80	Kettle Run - 50	333	369

Table 4-19: Observed and Simulated Exceedance Rates of the 400 cfu/100ml Instantaneous Fecal Coliform Standard			
Station	Reach	Exceedances of the Instantaneous Standard	
		Simulated	Observed
1APOE002.00	Popes Head Creek	14.91%	11.76%
1ABUL010.28	Bull Run	12.55%	12.31%
1ALII003.97	Little Bull Run	23.03%	11.11%
1AOCC024.74	Occoquan River	22.85%	21.74%
1ABRU007.58	Broad Run - 34	16.33%	18.52%
1ABRU020.12	Broad Run - 40	13.09%	29.27%
1ASOT001.44	South Run	7.05%	20.00%
1AKET000.80	Kettle Run - 50	55.54%	37.50%

4.10 Existing Bacteria Loading

The existing fecal coliform loading for each watershed was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2004. The standards used for fecal coliform concentrations were a geometric mean standard of 200 cfu/100 ml and an instantaneous standard of 400 cfu/100 ml. For *E. coli* concentrations, the standards used were a geometric mean of 126 cfu/100ml and an instantaneous standard of 235 cfu/100ml (DEQ, 2006). The *E. coli* concentrations in the impaired segments were calculated from fecal coliform concentrations using a regression based instream translator, which is presented below:

$$E.\ coli\ concentration\ (cfu/100\ ml) = 2^{-0.0172} \times (FC\ concentration\ (cfu/100ml))^{0.91905}$$

Below are presented the fecal coliform and *E. coli* existing load distribution by source for each of the impaired segment. The figures depicting the existing conditions for fecal coliform and *E. coli* geometric mean and instantaneous simulations are presented in Appendix F.

4.10.1 Broad Run (Segment VAN-A19R-01)

Distribution of the existing fecal coliform load by source in Broad Run (Segment VAN-A19R-01) is presented in **Table 4-20**. The corresponding *E. coli* loading is presented in **Table 4-21**. *E. coli* concentrations in the impaired Broad Run (VAN-A19R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-20** and **Table 4-21** show that direct deposition from cattle as well as loading from low and high residential areas are the predominant sources of bacteria in Broad Run (Segment VAN-A19R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct deposition loads from wildlife and cattle will dominate.

Table 4-20: Broad Run (VAN-A19R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	1.41E+12	2.00%
Cropland	4.09E+11	0.60%
Pasture	2.42E+12	3.40%
Low Density Residential	1.28E+13	17.90%
Commercial/Industrial	4.44E+12	6.20%
Water/Wetland	3.87E+10	0.10%
Other	4.11E+11	0.60%
High Density Residential	1.16E+13	16.20%
Cattle - Direct Deposition	3.38E+13	47.30%
Wildlife	4.12E+12	5.80%
Failed Septics & Straight Pipes	3.49E+10	0.00%
Point Source (General Permits)	1.38E+10	0.00%
Total	**7.14E+13**	**100.00%**

Table 4-21: Broad Run (VAN-A19R-01) E. coli Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	1.45E+11	2.4%
Cropland	4.65E+10	0.8%
Pasture	2.38E+11	3.9%
Low Density Residential	1.10E+12	18.1%
Commercial/Industrial	4.16E+11	6.8%
Water/Wetland	5.32E+09	0.1%
Other	4.66E+10	0.8%
High Density Residential	1.01E+12	16.6%
Cattle - Direct Deposition	2.68E+12	44.0%
Wildlife - Direct Deposition	3.88E+11	6.4%
Failed Septics & Straight Pipes	4.84E+09	0.1%
Point Source (General Permits)	8.71E+09	0.1%
Total	**6.09E+12**	**100.0%**

4.10.2 Broad Run (Segment VAN-A19R-02)

Distribution of the existing fecal coliform load by source in Broad Run (Segment VAN-A19R-02) is presented in **Table 4-22**. The corresponding *E. coli* loading is presented in **Table 4-23**. *E. coli* concentrations in the impaired Broad Run (VAN-A19R-02) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-22** and **Table 4-23** show that loading from low density residential areas and direct deposition from cattle and wildlife are the predominant sources of bacteria in Broad Run (Segment VAN-A19R-02) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate as well as the nonpoint source loads from pasture and cropland areas.

Table 4-22: Broad Run (VAN-A19R-02) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	4.05E+11	3.1%
Cropland	9.76E+10	0.7%
Pasture	5.36E+11	4.1%
Low Density Residential	2.96E+12	22.6%
Commercial/Industrial	2.93E+11	2.2%
Water/Wetland	1.55E+09	0.0%
Other	1.32E+10	0.1%
High Density Residential	0.00E+00	0.0%
Cattle - Direct Deposition	5.08E+12	38.7%
Wildlife	3.65E+12	27.8%
Failed Septics & Straight Pipes	3.71E+10	0.3%
Point Source (Individual VPDES and General Permits)	3.75E+10	0.3%
Total	**1.31E+13**	100.0%

Table 4-23: Broad Run (VAN-A19R-02) E. coli Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	4.60E+10	3.6%
Cropland	1.24E+10	1.0%
Pasture	5.95E+10	4.6%
Low Density Residential	2.86E+11	22.2%
Commercial/Industrial	3.42E+10	2.7%
Water/Wetland	2.76E+08	0.0%

Source	Annual Average E. Coli Loads	
	cfu/year	%
Other	1.98E+09	0.2%
High Density Residential	0.00E+00	0.0%
Cattle - Direct Deposition	4.70E+11	36.4%
Wildlife	3.47E+11	26.9%
Failed Septics & Straight Pipes	5.12E+09	0.4%
Point Source (Individual VPDES and General Permits)	3.24E+10	2.5%
Total	**1.29E+12**	100.0%

4.10.3 Broad Run (Segment VAN-A19R-05)

Distribution of the existing fecal coliform load by source in (Segment VAN-A19R-05) is presented in **Table 4-24**. The corresponding *E. coli* loading is presented in **Table 4-25**. *E. coli* concentrations in the impaired (VAN-A19R-05) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-24** and **Table 4-25** show that loading from low density residential areas, pasture, and direct deposition from cattle and wildlife are the predominant sources of bacteria in Broad Run (Segment VAN-A19R-05) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate as well as the nonpoint source loads from pasture and cropland areas. Under dry weather conditions, the direct-deposition loads from wildlife cattle will dominate.

Table 4-24: Broad Run (VAN-A19R-05) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	3.69E+11	3.6%
Cropland	1.41E+11	1.4%
Pasture	1.03E+12	10.2%
Low Density Residential	1.06E+12	10.5%
Commercial/Industrial	3.99E+11	3.9%
Water/Wetland	2.58E+08	0.0%
Other	0.00E+00	0.0%
High Density Residential	0.00E+00	0.0%
Cattle - Direct Deposition	3.13E+12	30.9%
Wildlife - Direct Deposition	3.96E+12	39.1%
Failed Septics & Straight Pipes	1.28E+10	0.1%
Point Source (General Permits)	1.38E+10	0.1%
Total	**1.01E+13**	**100.0%**

Table 4-25: Broad Run (VAN-A19R-05) E. *coli* Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	4.23E+10	4%
Cropland	1.75E+10	2%
Pasture	1.08E+11	11%
Low Density Residential	1.12E+11	11%
Commercial/Industrial	4.54E+10	4%
Water/Wetland	5.31E+07	0%
Other	0.00E+00	0%
High Density Residential	0.00E+00	0%
Cattle - Direct Deposition	3.01E+11	30%
Wildlife- Direct Deposition	3.74E+11	37%
Failed Septics & Straight Pipes	1.93E+09	0%
Point Source (General Permits)	8.71E+09	1%
Total	**1.01E+12**	**100%**

4.10.4 Kettle Run (Segment VAN-A19R-03)

Distribution of the existing fecal coliform load by source in Kettle Run (Segment VAN-A19R-03) is presented in **Table 4-26**. The corresponding *E. coli* loading is presented in **Table 4-27**. *E. coli* concentrations in the impaired (VAN-A19R-03) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-26** and **Table 4-27** show that loading from low density residential areas and direct deposition from cattle are the predominant sources of bacteria in Kettle Run (Segment VAN-A19R-03) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition load from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct deposition loads from cattle will dominate.

Table 4-26: Kettle Run (VAN-A19R-03) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	3.07E+11	1.8%
Cropland	2.96E+11	1.8%
Pasture	4.81E+11	2.9%
Low Density Residential	6.12E+12	36.7%
Commercial/Industrial	2.24E+11	1.3%
Water/Wetland	3.20E+09	0.0%
Other	7.63E+10	0.5%

Table 4-26: Kettle Run (VAN-A19R-03) Fecal Coliform Existing Load Distribution		
	Annual Average Fecal Coliform Loads	
Source	cfu/year	%
High Density Residential	2.94E+11	1.8%
Cattle - Direct Deposition	7.63E+12	45.7%
Wildlife-Direct Deposition	1.21E+12	7.2%
Failed Septics & Straight Pipes	3.41E+10	0.2%
Point Source (General Permits)	2.21E+10	0.1%
Total	**1.67E+13**	**100.0%**

Table 4-27: Kettle Run (VAN-A19R-03) E. *coli* Existing Load Distribution		
	Annual Average E. Coli Loads	
Source	cfu/year	%
Forest	3.56E+10	2%
Cropland	3.44E+10	2%
Pasture	5.39E+10	3%
Low Density Residential	5.58E+11	35%
Commercial/Industrial	2.66E+10	2%
Water/Wetland	5.37E+08	0%
Other	9.92E+09	1%
High Density Residential	3.43E+10	2%
Cattle - Direct Deposition	6.84E+11	43%
Wildlife-Direct Deposition	1.25E+11	8%
Failed Septics & Straight Pipes	4.74E+09	0%
Point Source (General Permits)	1.39E+10	1%
Total	**1.58E+12**	**100%**

4.10.5 South Run (Segment VAN-A19R-04)

Distribution of the existing fecal coliform load by source in South Run (Segment VAN-A19R-04) is presented in **Table 4-28**. The corresponding *E. coli* loading is presented in **Table 4-29**. *E. coli* concentrations in the impaired (VAN-A19R-04) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-28** and **Table 4-29** show that loading from low density residential areas and direct deposition from cattle are the predominant sources of bacteria in South Run (Segment VAN-A19R-04) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the direct deposition load from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the loads from cattle will dominate.

Table 4-28: South Run (VAN-A19R-04) Fecal Coliform Existing Load Distribution		
Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	7.89E+10	1.5%
Cropland	4.31E+09	0.1%
Pasture	1.56E+11	3.0%
Low Density Residential	3.24E+12	61.8%
Commercial/Industrial	1.53E+11	2.9%
Water/Wetland	4.12E+09	0.1%
Other	3.21E+09	0.1%
High Density Residential	2.22E+10	0.4%
Cattle - Direct Deposition	9.74E+11	18.6%
Wildlife-Direct Deposition	5.79E+11	11.0%
Failed Septics & Straight Pipes	1.91E+10	0.4%
Point Source (VPDES Individual Permit and General Permit)	8.69E+09	0.2%
Total	**5.24E+12**	**100.0%**

Table 4-29: South Run (VAN-A19R-04) E. *coli* Existing Load Distribution		
Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	1.02E+10	1.9%
Cropland	7.08E+08	0.1%
Pasture	1.92E+10	3.6%
Low Density Residential	3.11E+11	57.9%
Commercial/Industrial	1.88E+10	3.5%
Water/Wetland	6.79E+08	0.1%
Other	5.39E+08	0.1%
High Density Residential	3.19E+09	0.6%
Cattle - Direct Deposition	1.03E+11	19.2%
Wildlife-Direct Deposition	6.39E+10	11.9%
Failed Septics & Straight Pipes	2.78E+09	0.5%
Point Source (VPDES Individual Permit and General Permit)	2.69E+09	0.5%
Total	**5.37E+11**	**100.0%**

4.10.6 Popes Head Creek (Segment VAN-A23R-02)

Distribution of the existing fecal coliform load by source in Popes Head Creek (Segment VAN-A23R-02) is presented in **Table 4-30**. The corresponding *E. coli* loading is presented in **Table 4-31**. *E. coli* concentrations in the impaired segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-30** and **Table 4-31** show that loading from the urban areas are the predominant sources of bacteria in Popes Head Creek (Segment VAN-A23R-02) watershed. Under wet weather conditions, the nonpoint source loads from urban areas will dominate. Under dry weather conditions, the direct load from wildlife will dominate even though it constitutes just 1.6 percent of the total annual load.

Table 4-30: Popes Head Creek (VAN-A23R-02) Fecal Coliform Existing Load Distribution		
Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	1.51E+12	1.0%
Cropland	4.73E+11	0.3%
Pasture	1.72E+12	1.1%
Low Density Residential	2.56E+13	16.8%
Commercial/Industrial	1.55E+13	10.2%
Water/Wetland	6.18E+10	0.0%
Other	1.85E+12	1.2%
High Density Residential	1.03E+14	67.5%
Cattle - Direct Deposition	2.97E+11	0.2%
Wildlife-Direct Deposition	2.50E+12	1.6%
Failed Septics & Straight Pipes	1.57E+10	0.0%
Point Source (General Permits)	8.29E+09	0.0%
Total	**1.53E+14**	**100.0%**

Table 4-31: Popes Head Creek (VAN-A23R-02) E. *coli* Existing Load Distribution		
Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	1.54E+11	1.3%
Cropland	5.30E+10	0.5%
Pasture	1.74E+11	1.5%
Low Density Residential	2.08E+12	17.7%
Commercial/Industrial	1.31E+12	11.2%
Water/Wetland	8.17E+09	0.1%
Other	1.85E+11	1.6%
High Density Residential	7.47E+12	63.7%
Cattle - Direct Deposition	3.46E+10	0.3%
Wildlife-Direct Deposition	2.45E+11	2.1%
Failed Septics & Straight Pipes	2.32E+09	0.0%
Point Source (General Permits)	5.22E+09	0.0%
Total	**1.17E+13**	**100.0%**

4.10.7 Little Bull Run (Segment VAN-A21R-01)

Distribution of the existing fecal coliform load by source in Little Bull Run (Segment VAN-A21R-01) is presented in **Table 4-32**. The corresponding *E. coli* loading is presented in **Table 4-33**. *E. coli* concentrations in the impaired (VAN-A21R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-32** and **Table 4-33** show that loading from low and high density residential areas and direct deposition from cattle are the predominant sources of bacteria in Little Bull Run (Segment VAN-A21R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition load from pets and wildlife in residential areas will dominate. Under dry weather conditions, the loads from cattle will dominate.

Table 4-32: Little Bull Run (VAN-A21R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	3.90E+11	2.6%
Cropland	7.59E+10	0.5%
Pasture	4.00E+11	2.7%
Low Density Residential	2.49E+12	16.6%
Commercial/Industrial	4.80E+11	3.2%
Water/Wetland	2.53E+09	0.0%
Other	2.21E+11	1.5%
High Density Residential	2.80E+12	18.7%
Cattle - Direct Deposition	6.62E+12	44.2%
Wildlife-Direct Deposition	1.45E+12	9.7%
Failed Septics & Straight Pipes	8.95E+09	0.1%
Point Source (General Permits)	2.21E+10	0.1%
Total	**1.50E+13**	**100.0%**

Table 4-33: Little Bull Run (VAN-A21R-01) E. *coli* Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	4.44E+10	3.0%
Cropland	9.87E+09	0.7%
Pasture	4.54E+10	3.1%
Low Density Residential	2.45E+11	16.8%
Commercial/Industrial	5.37E+10	3.7%
Water/Wetland	4.33E+08	0.0%
Other	2.63E+10	1.8%
High Density Residential	2.72E+11	18.6%
Cattle - Direct Deposition	6.00E+11	41.1%
Wildlife-Direct Deposition	1.49E+11	10.2%
Failed Septics & Straight Pipes	1.38E+09	0.1%
Point Source (General Permits)	1.39E+10	1.0%
Total	**1.46E+12**	**100.0%**

4.10.8 Bull Run (Segment VAN-A23R-01)

Distribution of the existing fecal coliform load by source in Bull Run (segment VAN-A23R-01) is presented in **Table 4-34.** The corresponding *E. coli* loading is presented in **Table 4-35**. *E. coli* concentrations in the impaired Bull Run (VAN-A23R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-34** and **Table 4-35** show that loading from low density residential areas, and direct deposition from cattle and wildlife are the predominant sources of bacteria in the Bull Run (Segment VAN-A23R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct deposition loads from wildlife cattle will dominate.

Table 4-34: Bull Run (VAN-A23R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	2.32E+11	0.1%
Cropland	8.18E+08	0.0%
Pasture	4.56E+10	0.0%
Low Density Residential	1.32E+13	6.1%
Commercial/Industrial	4.43E+11	0.2%
Water/Wetland	8.09E+09	0.0%
Other	1.41E+11	0.1%
High Density Residential	1.04E+13	4.8%
Cattle - Direct Deposition	1.25E+14	58.2%
Wildlife-Direct Deposition	6.49E+13	30.2%
Failed Septics & Straight Pipes	2.46E+11	0.1%
Point Source (VPDES Individual Permits and General Permits)	6.63E+10	0.0%
Total	**2.15E+14**	**100.0%**

Table 4-35: Bull Run (VAN-A23R-01) E. *coli* Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	2.75E+10	0%
Cropland	1.54E+08	0%
Pasture	6.18E+09	0%
Low Density Residential	1.13E+12	7%
Commercial/Industrial	4.99E+10	0%
Water/Wetland	1.26E+09	0%
Other	1.74E+10	0%

Table 4-35: Bull Run (VAN-A23R-01) E. *coli* Existing Load Distribution		
Source	Annual Average E. Coli Loads	
	cfu/year	%
High Density Residential	9.04E+11	6%
Cattle - Direct Deposition	8.93E+12	56%
Wildlife-Direct Deposition	4.88E+12	30%
Failed Septics & Straight Pipes	2.91E+10	0%
Point Source (VPDES Individual Permits and General Permits)	4.18E+10	0%
Total	**1.60E+13**	**100%**

4.10.9

4.10.9 Occoquan River (Segment VAN-A20R-01)

Distribution of the existing fecal coliform load by source in the Occoquan River (Segment VAN-A20R-01) is presented in **Table 4-36**. The corresponding *E. coli* loading is presented in **Table 4-37**. *E. coli* concentrations in the impaired Occoquan River (VAN-A20R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-36** and **Table 4-37** show that loading from the urban areas are the predominant sources of bacteria in the Occoquan River (Segment VAN-A20R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife will dominate. Under wet weather conditions, the nonpoint source loads from urban areas will dominate.

Table 4-36: Occoquan River (VAN-A20R-01) Fecal Coliform Existing Load Distribution		
Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	4.20E+11	0.9%
Cropland	7.49E+10	0.2%
Pasture	1.60E+11	0.4%
Low Density Residential	1.94E+13	43.4%
Commercial/Industrial	2.23E+12	5.0%
Water/Wetland	9.57E+09	0.0%
Other	3.17E+11	0.7%
High Density Residential	1.76E+13	39.4%
Cattle - Direct Deposition	6.30E+11	1.4%
Wildlife-Direct Deposition	3.76E+12	8.4%
Failed Septics & Straight Pipes	3.83E+10	0.1%
Point Source (General Permits)	2.21E+10	0.0%
Total	**4.47E+13**	**100.0%**

Table 4-37: Occoquan River (VAN-A20R-01) E. *coli* Existing Load Distribution		
	Annual Average E. Coli Loads	
Source	**cfu/year**	**%**
Forest	4.75E+10	1.2%
Cropland	9.75E+09	0.3%
Pasture	1.96E+10	0.5%
Low Density Residential	1.61E+12	41.8%
Commercial/Industrial	2.20E+11	5.7%
Water/Wetland	1.47E+09	0.0%
Other	3.67E+10	1.0%
High Density Residential	1.47E+12	38.2%
Cattle - Direct Deposition	6.91E+10	1.8%
Wildlife-Direct Deposition	3.56E+11	9.2%
Failed Septics & Straight Pipes	5.26E+09	0.1%
Point Source (General Permits)	1.39E+10	0.4%
Total	**3.85E+12**	**100.0%**

5.0 Allocation

For the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River TMDLs, allocation analysis was the third stage in development. Its purpose was to develop the framework for reducing bacteria loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios were calculated using the following equation:

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

Where,

WLA = waste load allocation (point source contributions);

LA = load allocation (nonpoint source allocation); and

MOS = margin of safety.

Typically, several potential allocation strategies would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly fecal *coli*form geometric mean standard of 200 cfu/100 mL and the instantaneous fecal *coli*form standard of 400 cfu/100 mL with 0% exceedance. In terms of *E. coli*, incorporating an implicit MOS will require that the allocation scenario be designed to meet the monthly geometric mean standard of 126 cfu/100 mL and the instantaneous standard of 235 cfu/100 mL with 0 violations.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violations, and provides insight and direction in developing the TMDL allocations and implementation. Based on the sensitivity analysis, several allocation scenarios were developed. For each scenario developed, the percent of days water quality conditions violate the monthly geometric mean standard and instantaneous standard for *E. coli* were calculated. The results of the sensitivity analysis are presented in Appendix G.

5.3 Allocation Scenario Development

Allocation scenarios were modeled using the calibrated HSPF model to adjust the existing conditions until the water quality standard was attained. The TMDLs developed for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River were based on the Virginia water quality criteria for *E. coli*. As detailed in Section 1.2, the *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 mL, and that a maximum single sample concentration of *E. coli* shall not exceed 235 cfu/100 mL. According to the guidelines put forth by the DEQ (DEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform. The fecal coliform model output then processed to convert concentrations to *E. coli* using the following equation:

$$\log_2 (C_{ec}) = -0.0172+0.91905*\log2(c_{fc})$$

Where C_{ec} is the concentration of *E. coli* in cfu/100 mL, and C_{fc} is the concentration of fecal *coli*form in cfu/100 mL.

The pollutant concentrations were simulated over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met. The pollutant loads were calculated at the outlet of each impaired segment and include the loads from all upstream reaches and WLAs. The pollutant loads were calculated at the outlet of each individual watershed. The development of the allocation scenarios was an iterative process requiring numerous runs where each run was followed by an assessment of source reduction against the water quality target. The following sections present the waste load allocation (WLA) and load allocations (LA) for the nine impaired segments.

5.4 Waste Load Allocation

This section outlines the waste load allocations (WLA) for each impaired segment. It presents the existing and allocated loads for each permitted (VPDES and MS4) facility contributing to the impaired segment. The MS4 loads were calculated based on the MS4's specific acreage and the E. coli average loading rate (cfu/acre-yr) for the impaired segment. All the land-based E. coli loads were considered in the calculation of the MS4 loads, therefore the average land-based load reduction was assigned to the MS4. The wasteload allocation presented in the following sections includes regulated stormwater discharges from Phase I and Phase II MS4 regulated entities. Phase I MS4 operators include Fairfax County and Prince William County. Phase II MS4 entities include: Loudoun County; the City of Manassas; the City of Manassas Park; the City of Fairfax; MWAA Washington Dulles International Airport; Prince William County Schools; Fairfax County Schools; Northern Virginia Community College (Manassas Campus); Virginia Department of Transportation, Northern Virginia Urban Area. Land-based loads were allocated to the MS4 localities based on an area weighted method. The MS4 wasteload allocation is aggregated and presented by locality. The allocation represents the allowable loadings from all MS4 entities contained within the jurisdictional area of the locality. Due to the spatial overlap between the MS4 entities and the resulting uncertainty of the appropriate operator of the system, the MS4 loads are aggregated in the TMDL. For instance, certain roads within a county are maintained by VDOT, some by the county, and some by private subdivisions. Thus, it was not practical to separate out individual allocations to each MS4 permit holder.

The MS4 loads are considered as a Waste Load Allocation (WLA) and are proportionally subtracted from the land-based load allocation (LA). Bacteria loads only from municipal and domestic sewage point sources (not from industrial facilities) were included in the waste load allocations.

The existing load for general domestic permits is based on the allowable flowrate of 1,000 gal/day and a maximum e coli concentration of 126 cfu/100 ml. The allocated load for domestic sewage facilities is based on the actual design flow of the system as presented in **Table 3-16**. This load is computed by applying a factor of five to the actual design flow of the system to account for future growth. The general permits issued in 2001 have a discharge limit for fecal coliform, and the general permits issued in 2006 have a discharge limit for *E. coli*. While the growth-expanded WLA is presented individually for each facility, it will be allocated to both new and existing facilities at the discretion of the permitting agency staff through permit issuances.

In general, the waste load allocation for point sources under individual VPDES permits was set assuming that they were operating at five times their design flow at their permitted maximum average concentration.[1] The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation for the individual permitted facilities was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed on a first-come, first-served basis. All current permit limits remain in effect and can only be altered through the VADEQ permitting process. Allocation of bacteria loadings shall be determined at the discretion of DEQ staff.

5.5 Load Allocation Development

The reduction of loadings from nonpoint sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed in order to determine the final TMDL load allocation. Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the HSPF model for the hydrologic period of January 1995 to

[1] This approach was not applied to the waste load allocation determined for the Upper Occoquan Sewage Authority (UOSA) nor for the Vint Hill Farms Station WWTP facility. Waste load allocation determinations for these facilities are discussed in detail in Sections 5.13 and 5.10, respectively.

December 2004. **Table 5-1** shows the key load allocation scenarios that were implemented to arrive at the final TMDL allocations. It should be noted that these key scenarios were implemented for all segments. However, additional scenarios were also implemented when deemed necessary to attain the final TMDL. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.
- Scenario 1 represents elimination of human sources (septic systems and straight pipes).
- Scenario 2 represents the elimination of human sources (septic systems and straight pipes) as well as half the direct instream loading from livestock.
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock.
- Scenario 4 represents the direct instream loading from wildlife (all other sources are eliminated).
- Scenario 5 represents the elimination of the direct loading from nonpoint sources and a 50% reduction of the wildlife contribution.
- Scenario 6 represents the elimination of the direct loading from nonpoint sources and a 75% reduction of wildlife contribution

Table 5-1: TMDL Load Allocation Scenarios (%Reduction)

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife
0	0	0	0	0	0
1	100	0	0	0	0
2	100	50	0	0	0
3	100	100	0	0	0
4	100	100	100	100	0
5	100	100	0	0	50
6	100	100	0	0	75

The estimated load reductions and percent exceedences under each scenario for the different impaired segments derived from these allocation scenarios are presented separately in Appendix H. In addition, the percent of days the 126 cfu/100mL *E. coli* geometric mean water quality standard and the 235 cfu/100mL *E. coli* instantaneous water quality standard were violated under each scenario are presented.

5.5.1 Broad Run (VAN-A19R-01) Waste Load Allocation

There are five general domestic sewage permitted facilities discharging bacteria to Broad Run (segment VAN-A19R-01). The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in **Table 3-16**, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. **Table 5-2** shows the existing and allocated loads from general domestic dischargers in Broad Run (segment VAN-A19R-01). In addition, three industrial facilities possess individual VPDES permits in the Broad Run subwatershed (segment VAN-A19R-01). These facilities are not expected to discharge bacteria and thus do not have effluent limits for bacteria in their VPDES permits. Therefore, in this TMDL, a waste load allocation was not established for these industrial facilities.

Table 5-2: Broad Run (Segment VAN-A19R-01) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAG406071	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406079	Domestic Sewage Discharge	1.74E+09	3.48E+09	-
VAG406231	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406234	Domestic Sewage Discharge	1.74E+09	8.71E+08	-
VAG406248	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
Total		**8.71E+09**	**1.74E+10**	-

Within Broad Run (segment VAN-A19R-01) there are two MS4 localities requiring TMDL allocations. **Table 5-3** shows the waste load allocations for each MS4. The waste load allocations were based on each municipality's share of the contributing urbanized area of the impairment.

Table 5-3: Broad Run (Segment VAN-A19R-01) MS4s Waste load Allocation for *E. coli*					
Permit Number	**Individual MS4 Permit Holder**	**MS4 Location**	**Existing Load (cfu/yr)**	**Allocated Load (cfu/yr)**	**Reduction (%)**
VAR040063	City of Manassas	City of Manassas	5.99E+10	1.15E+10	81%
VAR040062	VDOT Urban Area				
VA0088595	Prince William County	Prince William County	2.88E+12	5.55E+11	81%
VAR040100	Prince William County Schools				
VAR040062	VDOT Urban Area				
Total			**2.94E+12**	**5.67E+11**	81%

5.5.2 Broad Run (VAN-A19R-01) Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Broad Run (Segment VAN-A19R-01) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 85% reduction of bacteria loading from agricultural and urban nonpoint sources.
- No reductions from the forested land (wildlife indirect loads)
- 81% reduction of bacteria loading from MS4 locations, reflecting weighted average of the reductions required from forest (0%) and urban land (85%)

Table 5-4 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-4: Broad Run (VAN-A19R-01) Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation (Excluding MS4s from the Land-based Loads)			
Land Use/Source	**Annual Average *E. coli* Loads (cfu/yr)**		**Reduction (%)**
	Existing	**Allocation**	
Forest	2.62E+09	2.62E+09	0%
Cropland	8.97E+08	1.30E+08	85%
Pasture	4.79E+09	6.19E+08	85%
Low Density Residential	2.30E+10	3.45E+09	85%
Commercial/Industrial	8.06E+09	1.11E+09	85%
Water/Wetland	1.01E+08	1.01E+08	0%
Other Urban	8.39E+08	1.26E+08	85%
High Density Residential	2.33E+10	3.00E+09	85%
Cattle - direct deposition	2.68E+12	0.00E+00	100%
Wildlife - direct deposition	3.88E+11	3.88E+11	0%
Failed Septic - direct deposition	4.84E+09	0.00E+00	100%
Point Source	8.71E+09	1.74E+10	-
MS4s	2.94E+12	5.67E+11	81%
Total loads /Overall reduction	**6.09E+12**	**9.84E+11**	**-**

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-1** and **Figure 5-2.** **Figure 5-1** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-2** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Broad Run (Segment VAN-A19R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Broad Run (VAN-A19R-01) is presented in **Table 5-5**.

Table 5-5: Broad Run (VAN-A19R-01) TMDL Allocation Plan Loads (cfu/year) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
5.84E+11*	3.99 E+11	IMPLICIT	9.84E+11

(*) includes the MS4 allocations

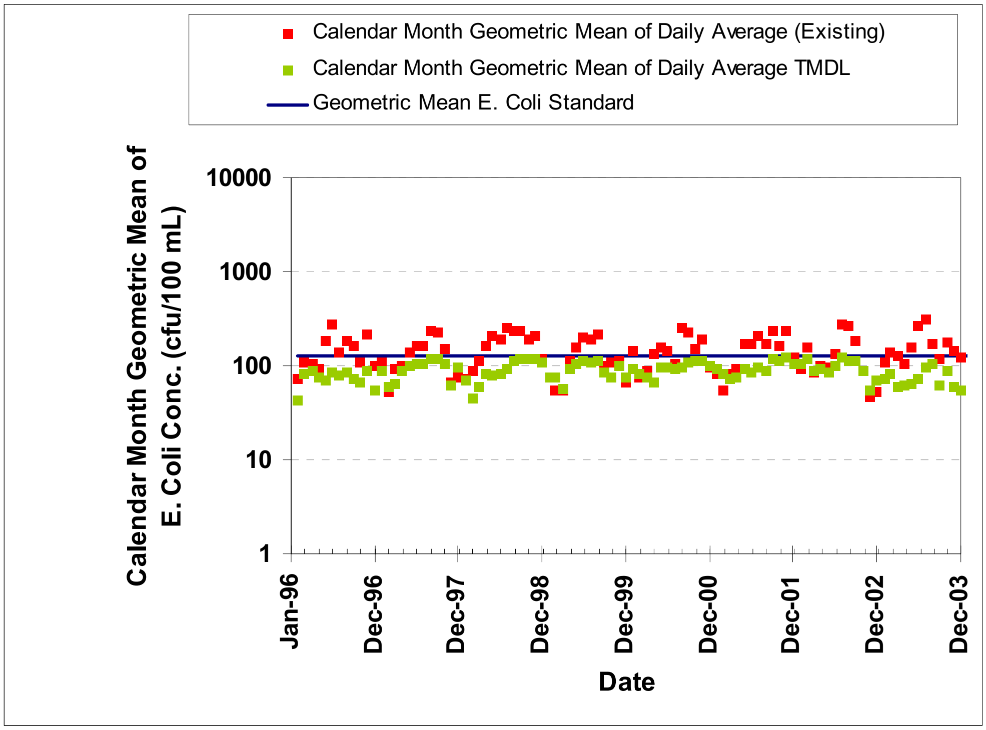

Figure 5-1: Broad Run VAN-A19R-01 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

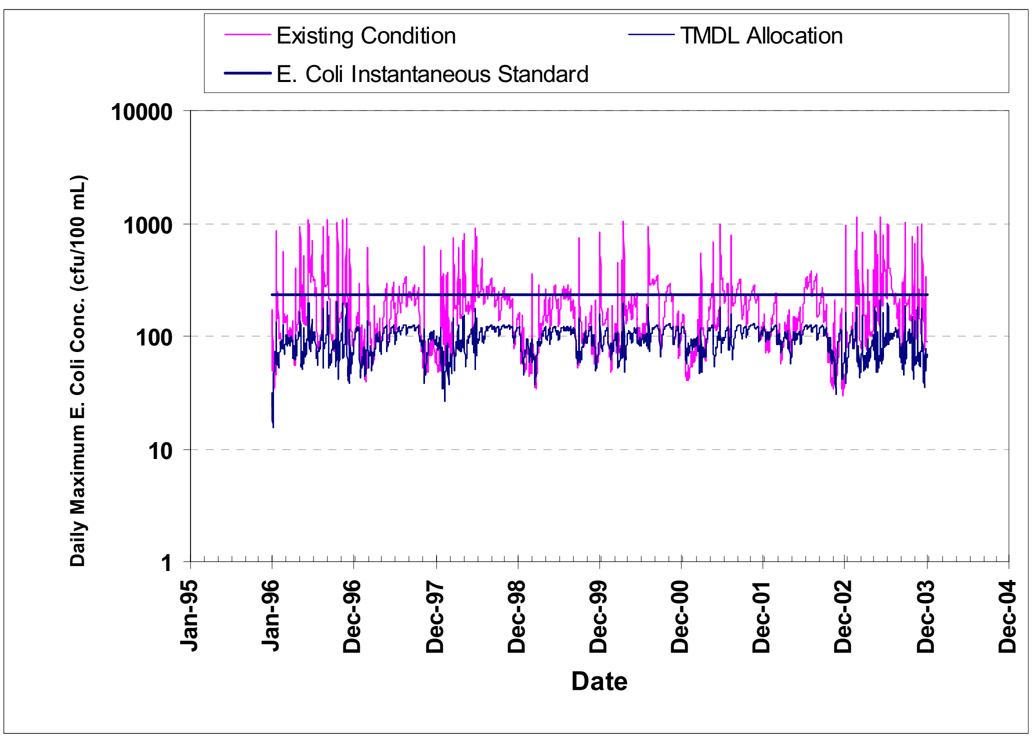

Figure 5-2: Broad Run VAN-A19R-01 Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.6 Broad Run (Segment VAN-A19R-02) TMDL

5.6.1 Broad Run (VAN-A19R-02) Waste Load Allocation

Two small sewage treatment facilities possess individual VPDES permits in the Broad Run subwatershed (segment VAN-A19R-02). In addition, 5 general domestic sewage permits are also issued within this watershed. The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in **Table 3-16**, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. **Table 5-6** presents the permitted dischargers and the computed waste load allocation for the Broad Run subwatershed (VAN-A19R-02). There are no MS4s permit holders within this segment of Broad Run (Segment VAN-A19R-02).

Table 5-6: Broad Run (Segment VAN-A19R-02) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VA0029092	Municipal	1.69E+10	8.44E+10	-
VA0064157	Municipal	6.75E+09	3.38E+10	-
VAG406316	Domestic Sewage Discharge	1.74E+09	2.61E+09	-
VAG406322	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406348	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406299	Domestic Sewage Discharge	1.74E+09	2.61E+09	-
VAG406038	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
Total		**3.24E+10**	**1.36E+11**	**-**

5.6.2 Broad Run (VAN-A19R-02) Allocation Plan

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the instantaneous water quality standard of 235 cfu/100mL for Broad Run (Segment VAN-A19R-02) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 90% reduction of bacteria loading from agricultural and urban nonpoint sources.
- 60% reduction of the direct instream loading from wildlife.

- No reductions from the forested land (wildlife indirect loads)

Table 5-7 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-7: Broad Run (VAN-A19R-02) Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	4.60E+10	4.60E+10	0
Cropland	1.24E+10	1.24E+09	90
Pasture	5.95E+10	5.95E+09	90
Low Density Residential	2.86E+11	2.86E+10	90
Commercial/Industrial	3.42E+10	3.42E+09	90
Water/Wetland	2.76E+08	2.76E+08	0
Other Urban	1.98E+09	1.98E+08	90
High Density Residential	0.00E+00	0.00E+00	90
Cattle - direct deposition	4.70E+11	0.00E+00	100
Wildlife - direct deposition	3.47E+11	1.39E+11	60
Failed Septic - direct deposition	5.12E+09	0.00E+00	100
Point Source	3.24E+10	1.36E+11	0
MS4s*	0.00E+00	0.00E+00	-
Total loads /Overall reduction	**1.29E+12**	**3.61E+11**	**-**

(*) there are no MS4s in Broad Run (VAN-A19R-02)

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-3** and **Figure 5-4. Figure 5-3** shows the calendar month geometric mean *E. coli* concentrations for the allocation condition, as well as the geometric mean concentrations under existing conditions**. Figure 5-4** shows the instantaneous *E. coli* concentrations under the allocations as well as the concentrations under existing conditions. For Broad Run (Segment VAN-A19R-02), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for this segment of Broad Run (VAN-A19R-02) is presented in **Table 5-8**.

Table 5-8: Broad Run (VAN-A19R-02) TMDL Allocation Plan Loads (cfu/year) for *E. coli*			
WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
1.36E+11	2.25E+11	IMPLICIT	3.61E+11

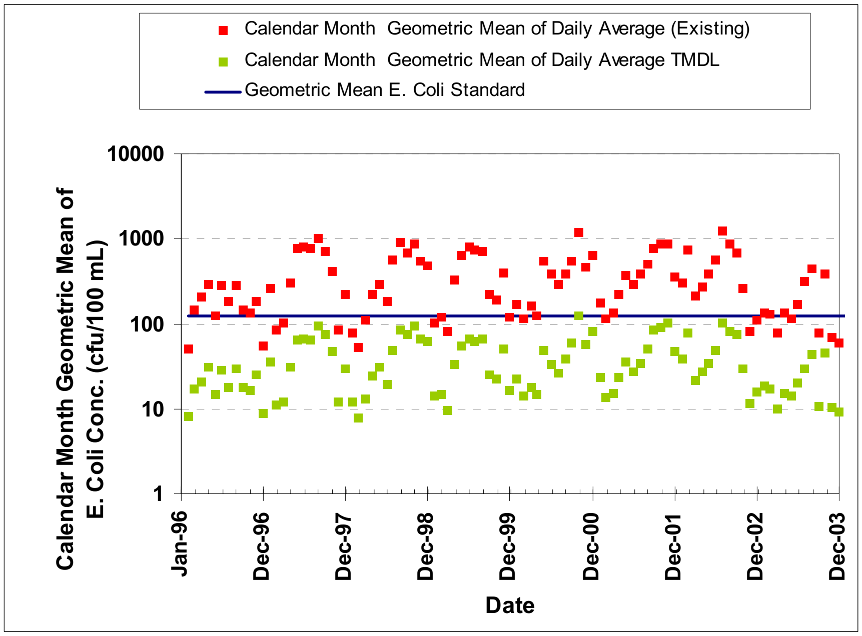

Figure 5-3: Broad Run Segment VAN-A19R-02 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

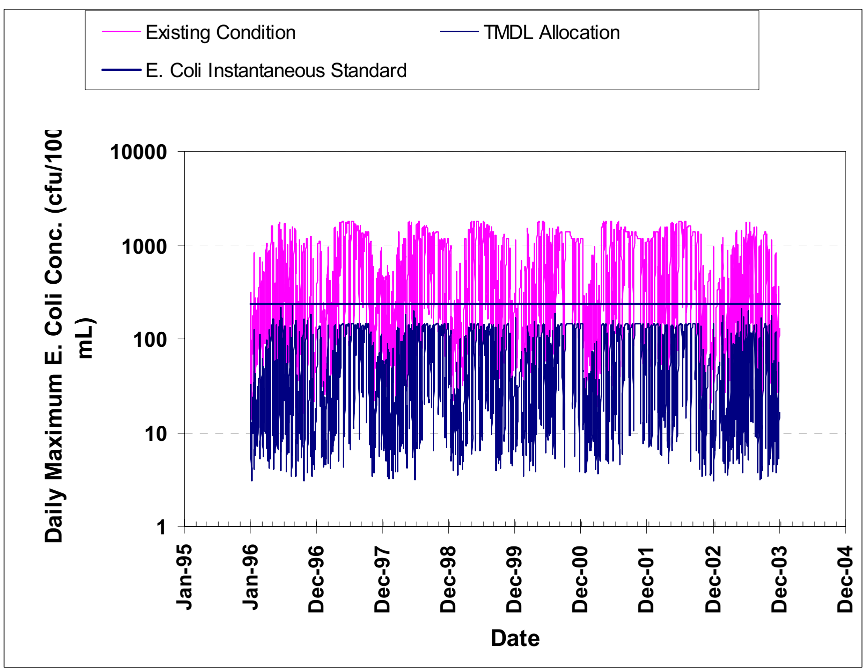

Figure 5-4: Broad Run Segment VAN-A19R-02 Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.7 Broad Run (Segment VAN-A19R-05) TMDL

5.7.1 Broad Run (VAN-A19R-05) Waste Load Allocation

There are no industrial or municipal VPDES permitted facilities currently discharging into the Broad Run subwatershed (segment VAN-A19R-05). However, five general domestic sewage permits have been issued within the watershed (**Table 5-9**). The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in Table 3-16, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. There are no MS4 permit holders within this segment of Broad Run (Segment VAN-A19R-05).

Table 5-9: Broad Run (Segment VAN-A19R-05) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VAG406314	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406260	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406157	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406308	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406313	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
Total		**8.70E+09**	**2.35E+10**	**-**

5.7.2 Broad Run (VAN-A19R-05) Allocation Plan

The requirements to meet calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Broad Run (Segment VAN-A19R-05) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 95% reduction of bacteria loading from agricultural and urban nonpoint sources.
- 80% reduction of the direct instream loading from wildlife.
- No reductions from the forested land (wildlife indirect loads)

Table 5-10 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-10: Broad Run (VAN-A19R-05) Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)
	Existing	Allocation	
Forest	4.23E+10	4.23E+10	0
Cropland	1.75E+10	8.74E+08	95
Pasture	1.08E+11	5.41E+09	95
Low Density Residential	1.12E+11	5.59E+09	95
Commercial/Industrial	4.54E+10	2.27E+09	95
Water/Wetland	5.31E+07	5.31E+07	0
Other Urban	0.00E+00	0.00E+00	95
High Density Residential	0.00E+00	0.00E+00	95
Cattle - direct deposition	3.01E+11	0.00E+00	100
Wildlife - direct deposition	3.74E+11	7.49E+10	80
Failed Septic - direct deposition	1.93E+09	0.00E+00	100
Point Source	8.70E+09	2.35E+10	N/A
MS4s*	0.00E+00	0.00E+00	-
Total loads /Overall reduction	**1.01E+12**	**1.55E+11**	**-**

(*) there are no MS4s in Broad Run (VAN-A19R-05)

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-5** and **Figure 5-6.** **Figure 5-5** shows the calendar month geometric mean *E. coli* loading, as well as geometric mean concentrations under existing conditions**. Figure 5-6** shows the instantaneous *E. coli* concentrations under the allocations, as well as the concentrations under existing conditions. For Broad Run (Segment VAN-A19R-05), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Broad Run (VAN-A19R-05) Creek is presented in **Table 5-11**.

Table 5-11: Broad Run (VAN-A19R-05) TMDL Allocation Plan Loads (cfu/year) for *E. coli*

WLA(Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
2.35E+10	1.31E+11	IMPLICIT	1.55E+11

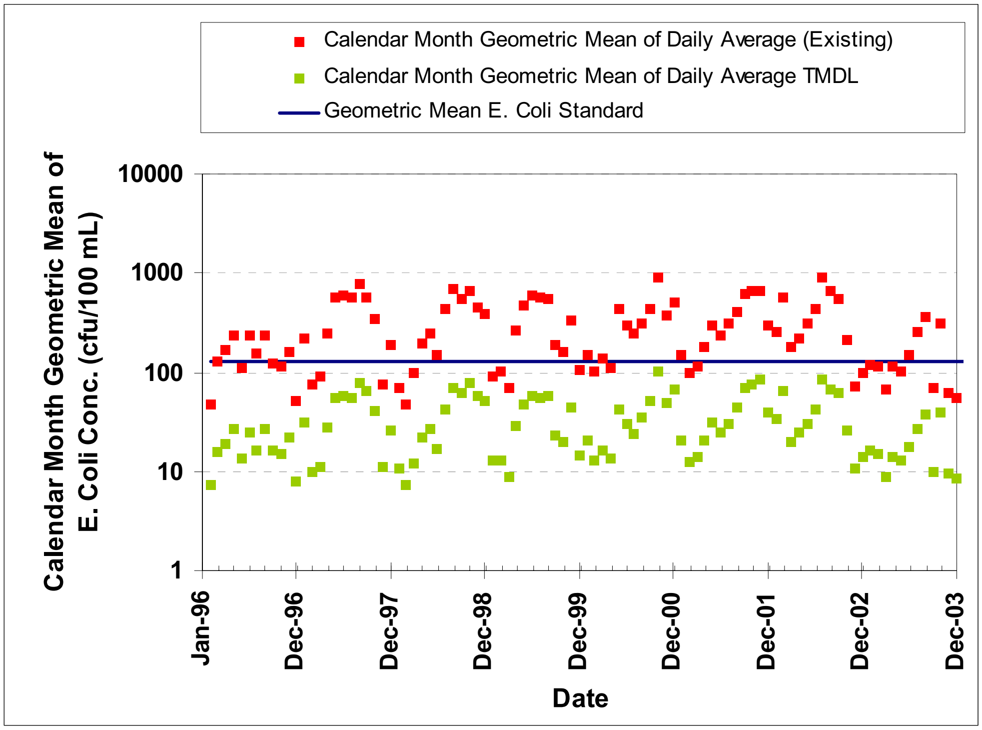

Figure 5-5: Broad Run Segment VAN-A19R-05 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

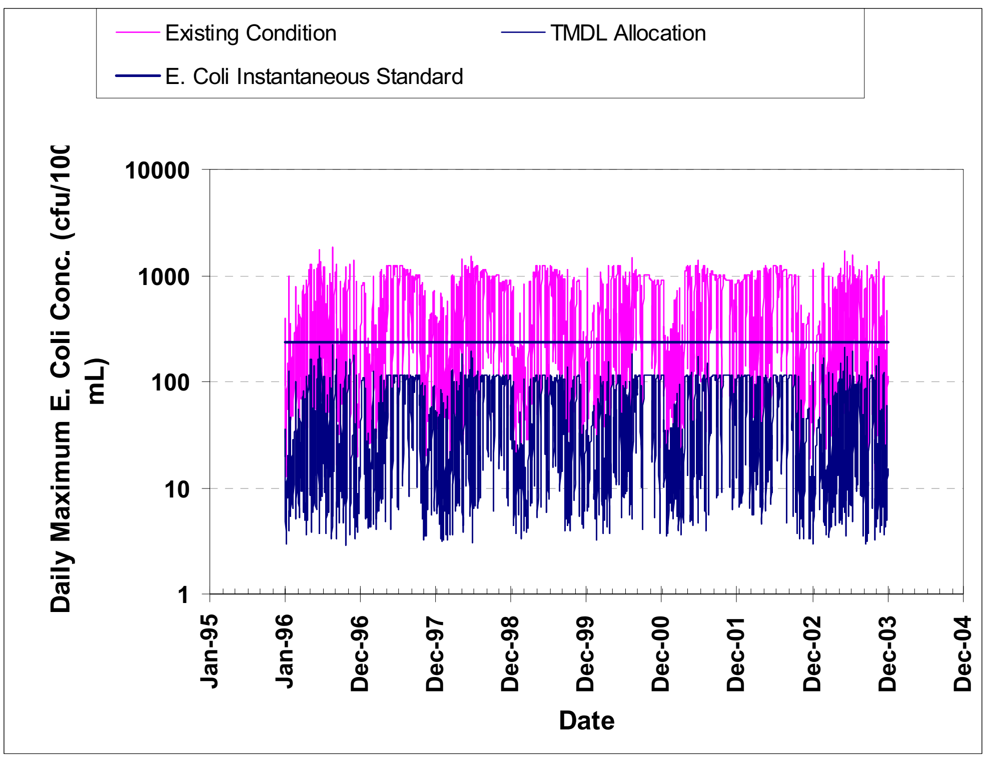

Figure 5-6: Broad Run Segment VAN-A19R-05 Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.8 Kettle Run (Segment VAN-A19R-03) TMDL

5.8.1 Kettle Run (VAN-A19R-03) Waste Load Allocation

There are no municipal individual VPDES permitted facilities currently discharging into Kettle Run (Segment VAN-A19R-03). However, there are eight general domestic permitted facilities in the watershed (**Table 5-12**). The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in Table 3-16, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. There are no MS4 permit holders within this segment of Kettle Run (VAN-A19R-03).

Although currently no VPDES dischargers are located within the watershed, the permit of Vint Hill Farms Station (VA002450) states that if the facility discharges more than 0.246 MGD, the outfall will be relocated from South Run to Kettle Run. Therefore, the allocated load for Kettle Run includes the potential future relocated discharge of Vint Hill based on the highest permitted design flow of 0.95 MGD adjusted to account for the expansion of five-times the design flow limits and bacteria concentrations at the existing *E-coli* standard of 126 cfu/100mL.

Table 5-12: Kettle Run (VAN-A19R-03) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAG406174	Domestic Sewage Discharge	1.74E+09	6.96E+09	-
VAG406271	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406292	Domestic Sewage Discharge	1.74E+09	6.53E+09	-
VAG406326	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406332	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406333	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406339	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406233	Domestic Sewage Discharge	1.74E+09	8.71E+09	-
VA002460	Municipal	-	8.25E+12	-
Total		**1.39E+10**	**8.30E+12**	**-**

5.8.2 Kettle Run (VAN-A19R-03) Allocation Plan

The requirements to meet calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Broad Run (Segment VAN-A19R-05) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 95% reduction of bacteria loading from agricultural and urban nonpoint sources.
- 50% reduction of the direct instream loading from wildlife.
- No reductions from the forested land (wildlife indirect loads)

Table 5-13 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-13: Kettle Run VAN-A19R-03 Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation (Excluding MS4s from the Land-based Loads)

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)
	Existing	Allocation	
Forest	3.43E+10	3.43E+10	0.0%
Cropland	3.07E+10	1.54E+09	95.0%
Pasture	4.81E+10	2.40E+09	95.0%
Low Density Residential	4.98E+11	2.49E+10	95.0%
Commercial/Industrial	2.37E+10	1.19E+09	95.0%
Water/Wetland	4.79E+08	4.79E+08	0.0%
Other Urban	8.85E+09	4.43E+08	95.0%
High Density Residential	3.06E+10	1.54E+09	N/A
Cattle - direct deposition	6.84E+11	0.00E+00	N/A
Wildlife - direct deposition	1.25E+11	6.27E+10	50.0%
Failed Septic - direct deposition	4.74E+09	0.00E+00	100.0%
Point Source#	1.39E+10	8.30E+12	NA
MS4s*	0.00E+00	0.00E+00	-
Total loads /Overall reduction	**1.50E+12**	**8.43E+12**	**-**

(*) there are no MS4s in Kettle Run (VAN-A19R-03)
(#) Although there are currently no VPDES point source dischargers in the watershed, the WLA includes the potential future relation of the Vint Hill facility to Kettle Run as well as a growth factor of 5 times the maximum permitted design flow.

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-7** and **Figure 5-8.** **Figure 5-7** shows the calendar month geometric mean *E. coli* concentrations, as well as geometric mean concentrations under existing conditions**.** **Figure 5-8** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Kettle Run

(Segment VAN-A19R-03), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Kettle Run is presented in **Table 5-14**.

Table 5-14: Kettle Run TMDL Allocation Plan Loads (cfu/year) for *E. coli*

WLA(Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
8.30E+12	1.29E+11	IMPLICIT	8.43E+12

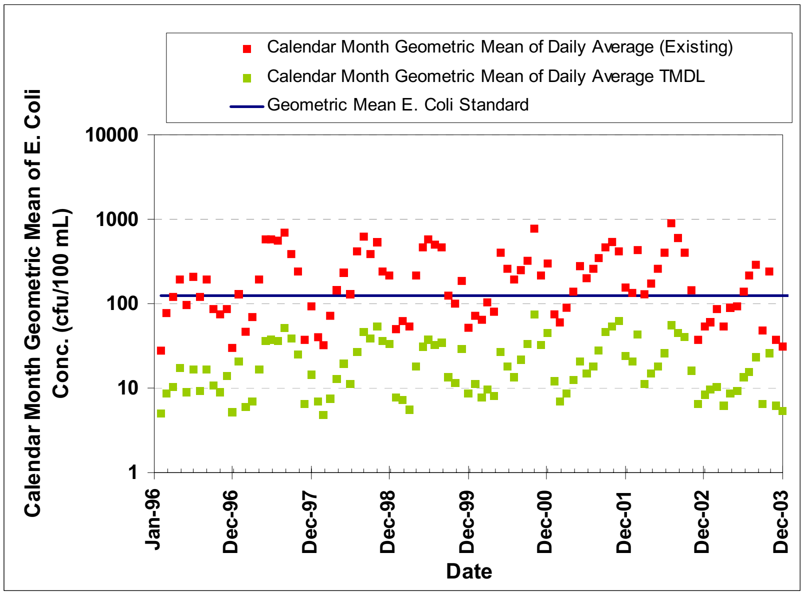

Figure 5-7: Kettle Run Segment VAN-A19R-03 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

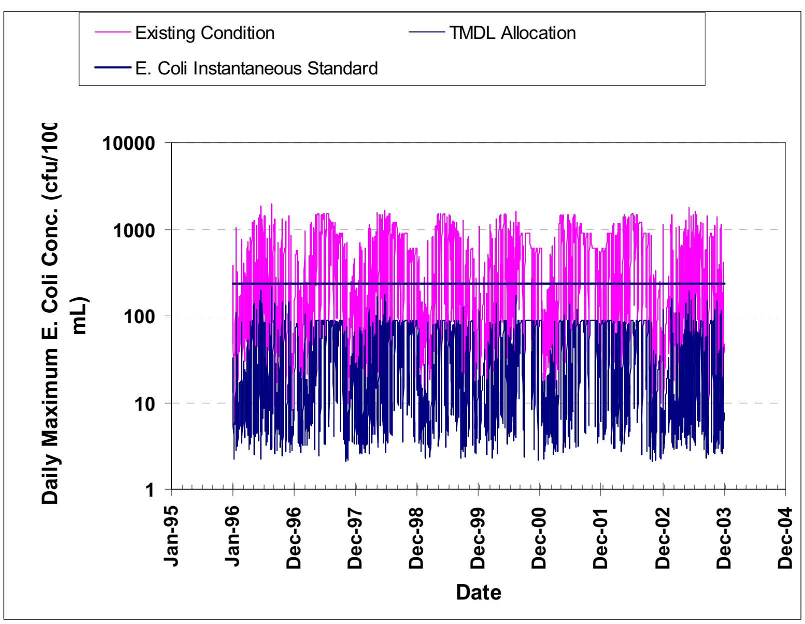

Figure 5-8: Kettle Run Segment VAN-A19R-03 Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.9 South Run (Segment VAN-A19R-04) TMDL

5.9.1 South Run (VAN-A19R-04) Waste Load Allocation

There is one (1) individual VPDES permit and one (1) general domestic sewage permit issued in the in South Run watershed (segment VAN-A19R-04) containing effluent limits for bacteria. The VPDES permitted facility is the Vint Hill Farms Station WWTP (VPDES Permit Number VA002046). The waste load allocation for this facility was established at the current design flow and a permitted average bacteria concentration of 126 cfu/100mL. The expansion factor of five times the current design flow was not applied for South Run as the permit requires the outfall location to be moved from South Run to Kettle Run if the facility expands from the current design flow of 0.246 MGD. Therefore, Vint Hill's future growth wasteload allocation is included in the Kettle Run TMDL (Section 5.8). The waste load allocation for the general domestic sewage permit was computed based on the design flow as listed in Table 3-16, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of the existing permit in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. **Table 5-15** shows the existing and allocated loadings from the permitted point source dischargers in the watershed. There are no MS4 permit holders within this segment of South Run (VAN-A19-R04).

Table 5-15: South Run (Segment VAN-A19R-04) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VA0020460	Municipal	4.29E+11	4.29E+11	-
VAG406134	Domestic Sewage Discharge	1.74E+09	2.61E+09	-
Total		**4.31E+11**	**4.32E+11**	**-**

5.9.2 South Run (VAN-A19R-04) Allocation Plan

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the instantaneous water quality standard of 235 cfu/100mL for South Run are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 95% reduction of bacteria loading from agricultural and urban nonpoint sources.
- 50% reduction of the direct instream loading from wildlife.
- No reductions from the forested land (wildlife indirect loads)
- 92% reduction of bacteria loading from MS4 locations, reflecting weighted average of the reductions required from forest (0%) and urban land (95%)

Table 5-16 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-16: South Run VAN-A19R-04 Distribution of Annual Average E. coli Load under Existing Conditions and TMDL Allocation (Excluding MS4s from the Land-Based Loads)

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)
	Existing	Allocation	
Forest	7.01E+09	7.01E+09	0%
Cropland	4.87E+08	1.81E+07	95%
Pasture	1.32E+10	4.89E+08	95%
Low Density Residential	2.14E+11	7.89E+09	95%
Commercial/Industrial	1.30E+10	4.79E+08	95%
Water/Wetland	4.67E+08	4.67E+08	0%
Other Urban	3.71E+08	1.38E+07	95%
High Density Residential	2.20E+09	8.10E+07	95%
Cattle - direct deposition	1.03E+11	0.00E+00	100%
Wildlife - direct deposition	6.39E+10	3.19E+10	50%
Failed Septic - direct deposition	2.78E+09	0.00E+00	100%
MS4*	0.00E+00	0.00E+00	-
Point Source	4.31E+11	4.32E+11	0%
Total loads /Overall reduction	**8.51E+11**	**4.80E+11**	**43%**

(*) there are no MS4s in South Run (VAN-A19R-04)

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-9** and **Figure 5-10.** **Figure 5-9** shows the calendar month geometric mean *E. coli* concentrations, as well as geometric mean loading under existing conditions**.** **Figure 5-10** shows the instantaneous *E. coli* concentrations under the allocations, as well as the concentrations under existing conditions. For South Run (Segment VAN-A19R-04), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for South Run is presented in **Table 5-17**.

Table 5-17: South Run Segment VAN-A19R-04 TMDL Allocation Plan Loads (cfu/year) for *E. coli*			
WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
4.32E+11	4.83E+10	IMPLICIT	4.80E+11

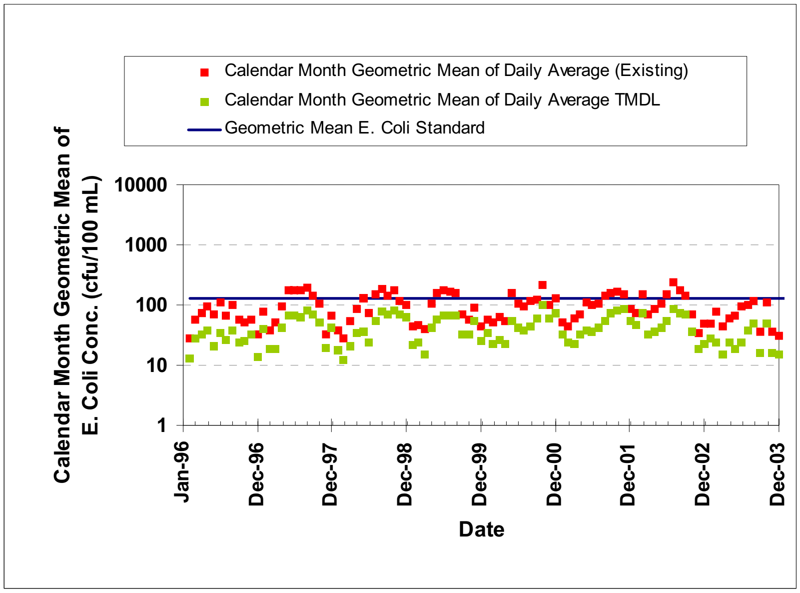

Figure 5-9: South Run Segment VAN-A19R-04 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

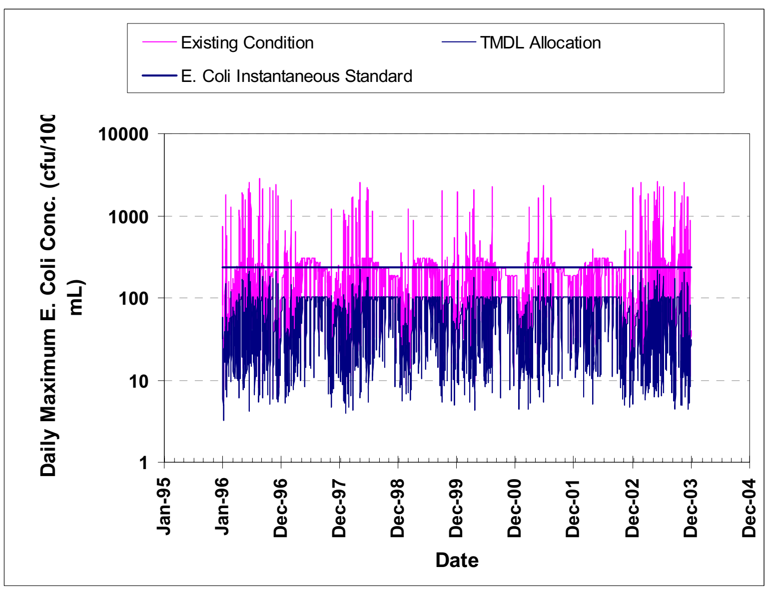

Figure 5-10: South Run Segment VAN-A19R-04 Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.10 Popes Head Creek (Segment VAN-A23R-02) TMDL

5.10.1 Popes Head Creek (VAN-A23R-02) Waste Load Allocation

There are no individual municipal VPDES permitted facilities currently discharging into Popes Head Creek (Segment VAN-A23R-02). However, there are three general permitted facilities discharging into this watershed (**Table 5-18**). The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in **Table 3-16**, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. This is reflected in **Table 5-20** showing the TMDL allocation plan for Popes Head Creek (Segment VAN-A23R-02).

Table 5-18: Popes Head Creek (Segment (VAN-A23R-02)) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAG406296	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406202	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406252	Domestic Sewage Discharge	1.74E+09	8.71E+09	-
Total		**5.22E+09**	**1.78E+10**	**-**

Within Popes Head Creek (Segment VAN-A23R-02) there are four (4) MS4s permits requiring TMDL allocations. **Table 5-19** shows the waste load allocations for each MS4. The waste load allocations were based on each municipality's share of the contributing urbanized area of the impairment.

Table 5-19: Popes Head Creek (Segment VAN-A23R-02) MS4s Waste load Allocation for E. coli

Permit Number	MS4 Permit Holder	MS4 Location	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VA0088587	Fairfax County	Fairfax County	1.08E+13	6.83E+11	94%
VAR040104	Fairfax County Public Schools				
VAR040062	VDOT Urban Areas				
VAR040064	City of Fairfax	City of Fairfax	1.62E+11	1.03E+10	94%
VAR040062	VDOT Urban Areas				
Total			**1.10E+13**	**6.94E+11**	**94%**

5.10.2 Popes Head Creek (VAN-A23R-02) Allocation Plan

The requirements to meet calendar month *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the instantaneous water quality standard of 235 cfu/100mL for Popes Head Creek are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 95% reduction of bacteria loading from agricultural and urban nonpoint sources.
- 52% reduction of the direct instream loading from wildlife.
- No reductions from the forested land (wildlife indirect loads)

Table 5-20 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-20: Popes Head Creek VAN-A23R-02 Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation (Excluding MS4s from the Land-based Loads)

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	6.47E+09	6.47E+09	0%
Cropland	2.35E+09	1.17E+08	95%
Pasture	8.21E+09	4.11E+08	95%
Low Density Residential	9.66E+10	4.83E+09	95%
Commercial/Industrial	5.53E+10	2.76E+09	95%
Water/Wetland	3.64E+08	3.64E+08	0%
Other Urban	7.99E+09	3.99E+08	95%
High Density Residential	3.36E+11	1.68E+10	95%
Cattle - direct deposition	3.46E+10	0.00E+00	100%
Wildlife - direct deposition	2.45E+11	1.18E+11	52%
Failed Septic - direct deposition	2.32E+09	0.00E+00	100%
Point Source	5.22E+09	1.78E+10	NA
MS4s	1.09E+13	6.94E+11	94%
Total loads /Overall reduction	**1.18E+13**	**8.61E+11**	-

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-11** and **Figure 5-12.** **Figure 5-11** shows the calendar month geometric mean *E. coli* concentrations, as well as geometric mean concentrations under existing conditions**.** **Figure 5-12** shows the instantaneous *E. coli* concentrations under the allocations, as well as the concentrations under existing conditions. For Popes Head Creek (Segment VAN-A23R-02), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Popes Head Creek is presented in **Table 5-21**.

Table 5-21: Popes Head Creek Segment Allocation Plan Loads (cfu/year) for *E. coli*

WLA (Point Sources)	LA (Nonpoint Sources)	MOS (Margin of safety)	TMDL
7.12E+11*	1.50E+11	IMPLICIT	8.61E+11

(*) includes the MS4 allocations

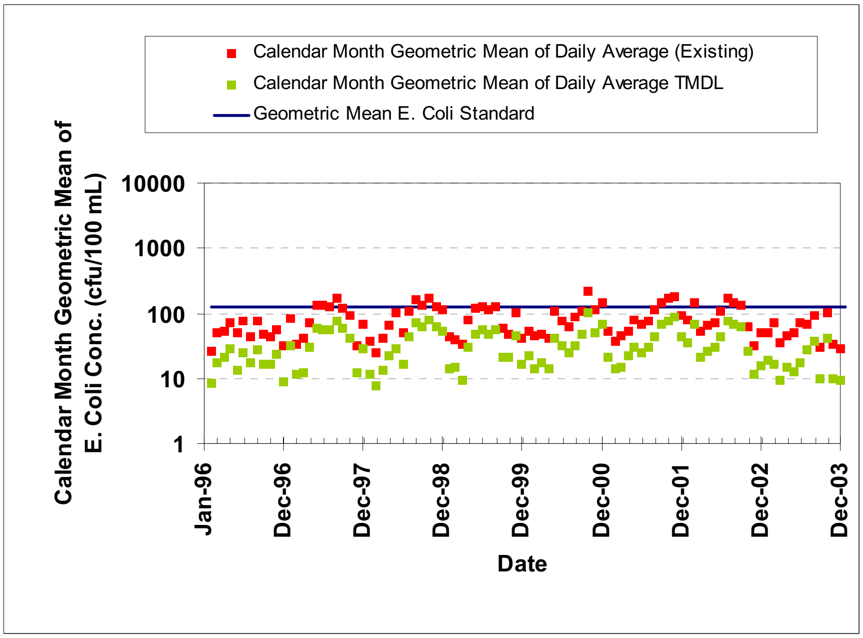

Figure 5-11: Popes Head Creek Segment VAN-A23R-02 Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario

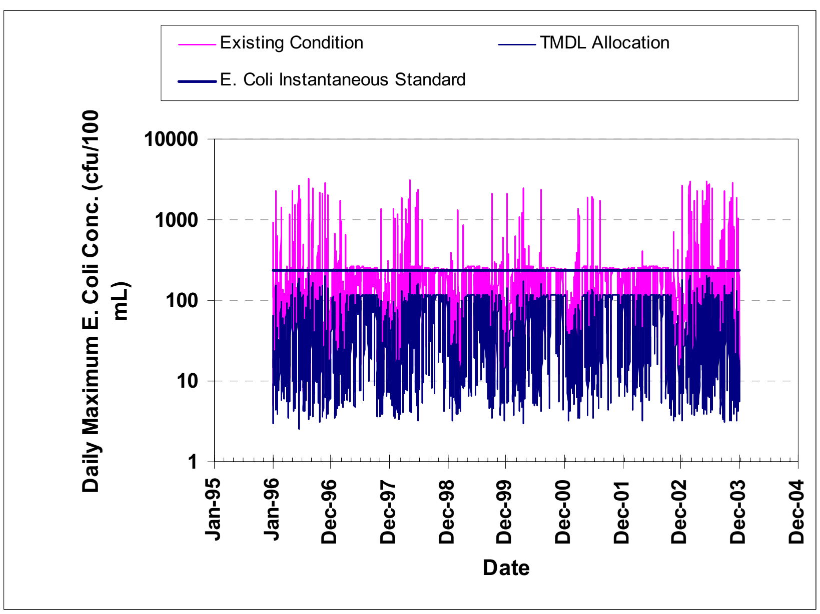

Figure 5-12: Popes Head Creek Segment VAN-A23R-02 Instantaneous *E. coli* Concentrations under Existing Conditions and Allocation Scenario

5.11 Little Bull Run (Segment VAN-A21R-01) TMDL

5.11.1 Little Bull Run (VAN-A21R-01) Waste Load Allocation

There are no industrial or municipal VPDES permitted facilities currently discharging into the Little Bull Run watershed (segment VAN-A21R-01). However, there are eight general domestic sewage permits within the watershed (**Table 5-22**). The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in **Table 3-16**, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. In addition, there are no MS4 permit holders within the Little Bull Run drainage (segment VAN-A21R-01).

Table 5-22: Little Bull Run Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAG406065	Domestic Sewage Discharge	1.74E+09	2.61E+09	-
VAG406076	Domestic Sewage Discharge	1.74E+09	6.96E+09	-
VAG406133	Domestic Sewage Discharge	1.74E+09	6.53E+09	-
VAG406224	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406109	Domestic Sewage Discharge	1.74E+09	6.53E+08	-
VAG406165	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406298	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406040	Domestic Sewage Discharge	1.74E+09	4.35E+09	-
Total		**1.39E+10**	**3.29E+10**	**-**

5.11.2 Little Bull Run (VAN-A21R-01) Allocation Plan

The requirements to meet calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Little Bull Run are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 90% reduction of bacteria loading from agricultural and urban nonpoint sources.
- No reductions from the forested land (wildlife indirect loads)

Table 5-23 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-23: Little Bull Run Segment VAN-A21R-01 Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)
	Existing	Allocation	
Forest	4.44E+10	4.44E+10	0
Cropland	9.87E+09	9.87E+08	90
Pasture	4.54E+10	4.54E+09	90
Low Density Residential	2.45E+11	2.45E+10	90
Commercial/Industrial	5.37E+10	5.37E+09	90
Water/Wetland	4.33E+08	4.33E+08	0
Other Urban	2.63E+10	2.63E+09	90
High Density Residential	2.72E+11	2.72E+10	90
Cattle - direct deposition	6.00E+11	0.00E+00	100
Wildlife - direct deposition	1.49E+11	1.49E+11	0
Failed Septic - direct deposition	1.38E+09	0.00E+00	100
Point Sources	1.39E+10	3.29E+10	-
MS4s*	0.00E+00	0.00E+00	-
Total loads /Overall reduction	**1.46E+12**	**2.92E+11**	

(*) there are no MS4s in Broad Run (VAN-A19R-05)

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-13** and **Figure 5-14. Figure 5-13** shows the calendar month geometric mean *E. coli* concentrations, as well as geometric mean loading under existing conditions**. Figure 5-14** shows the instantaneous *E. coli* concentrations under the allocations, as well as the concentrations under existing conditions. For Little Bull Run (Segment VAN-A21R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Little Bull Run is presented in **Table 5-24**.

Table 5-24: Little Bull Run Segment VAN-A21R-01 TMDL Allocation Plan Loads (cfu/year) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
3.29E+10	2.59E+11	IMPLICIT	2.92E+11

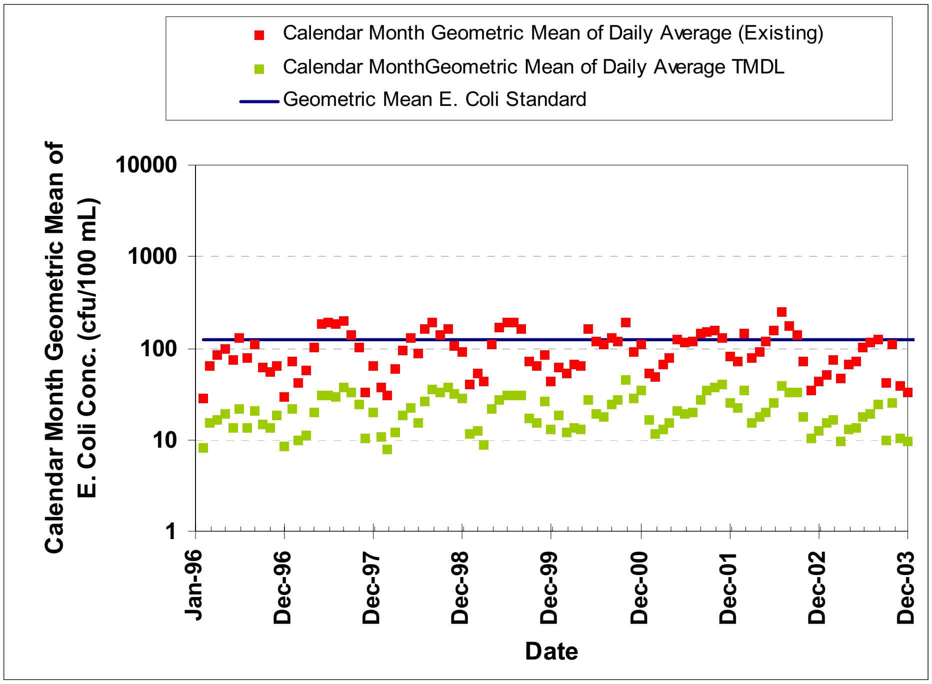

Figure 5-13: Little Bull Run Segment VAN-A21R-01 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

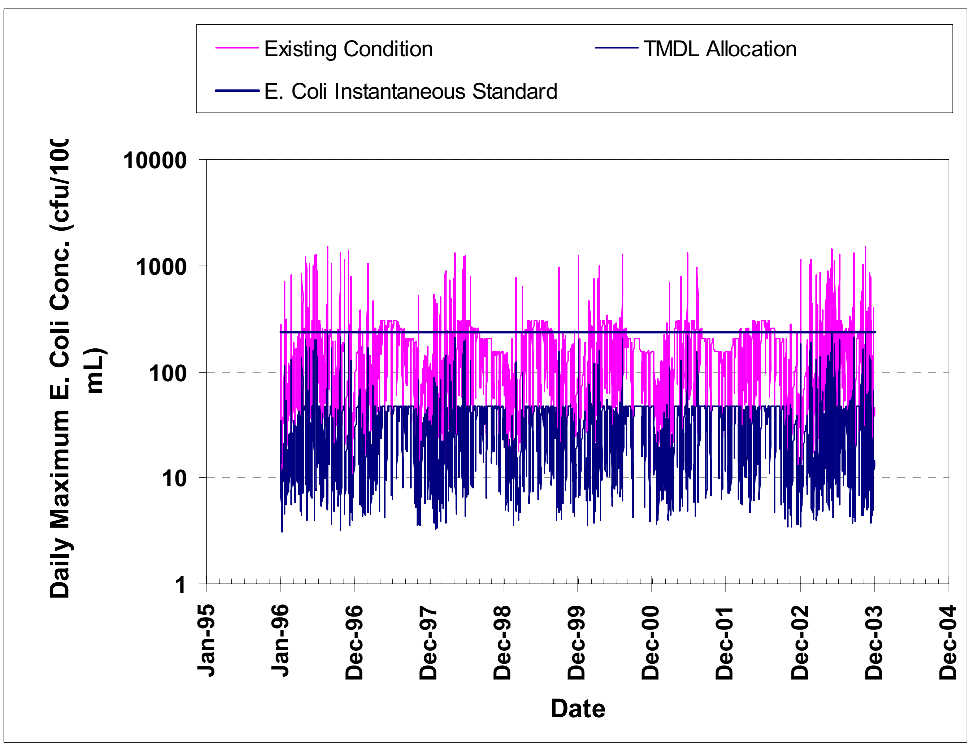

Figure 5-14: Little Bull Run Segment VAN-A21R-01 Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.12 Bull Run (Segment VAN-A23R-01) TMDL

5.12.1 Bull Run (VAN-A23R-01) Waste Load Allocation

There are seven individual VPDES permits issued in the Bull Run subwatershed (VAN-A23R-01) however, only two of those contain effluent limits for bacteria discharges (UOSA, VA0024988; and Evergreen Country Club, VA0087891). In addition, there are 24 domestic sewage permitted facilities also discharging into the Bull Run watershed. For Evergreen Country Club (VA0087891) the waste load allocation was computed based on the maximum permitted design flow of the facility with an expansion factor of five times the design flow included in the computation. The waste load allocation for UOSA was computed based on an expansion from the current design flow of 64 MGD to 85 MGD. This expansion is considered as the potential capacity for the facility. The waste load allocation for the domestic sewage facilities was computed based on the design flow for each facility as listed in Table 3-16, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff. **Table 5-25** shows the loading from the permitted point source dischargers in the watershed.

Table 5-25: Bull Run (Segment VAN-A23R-01) Waste load Allocation for E. coli

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VA0024988	Municipal	1.11E+14	1.11E+14	-
VA0087891	Municipal	1.35E+10	6.75E+10	-
VAG406315	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406236	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406272	Domestic Sewage Discharge	1.74E+09	4.35E+08	-
VAG406295	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406300	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406329	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406330	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406094	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406099	Domestic Sewage Discharge	1.74E+09	4.35E+09	-
VAG406273	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406242	Domestic Sewage Discharge	1.74E+09	8.71E+09	-
VAG406240	Domestic Sewage Discharge	1.74E+09	8.71E+09	-
VAG406221	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406247	Domestic Sewage Discharge	1.74E+09	3.92E+09	-

Table 5-25: Bull Run (Segment VAN-A23R-01) Waste load Allocation for E. coli				
Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAG406259	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406270	Domestic Sewage Discharge	1.74E+09	2.26E+09	-
VAG406209	Domestic Sewage Discharge	1.74E+09	4.79E+09	-
VAG406162	Domestic Sewage Discharge	1.74E+09	4.35E+09	-
VAG406297	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406319	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406280	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406057	Domestic Sewage Discharge	1.74E+09	3.48E+09	-
VAG406171	Domestic Sewage Discharge	1.74E+09	4.35E+09	-
VAG406009	Domestic Sewage Discharge	1.74E+09	8.27E+08	-
Total		**1.11E+14**	**1.11E+14**	

Within Bull Run (segment VAN-A23R-01) there are nine (9) MS4s permits requiring TMDL allocations. **Table 5-27** shows the waste load allocations for each MS4. The waste load allocations were based on each municipality's share of the contributing urbanized area of the impairment.

Table 5-27: Bull Run (Segment VAN-A23R-01) MS4s Waste load Allocation for *E. coli*					
Permit Number	MS4 Permit Holder	MS4 Location	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VA0088587	Fairfax County	Fairfax County	6.81E+11	7.61E+10	89%
VAR040104	Fairfax County Public Schools				
VAR044062	VDOT Urban Area				
VAR040067	Loudon County	Loudon County	1.18E+11	1.32E+10	89%
VAR040062	VDOT Urban Area				
VAR040063	City of Manassas	City of Manassas	6.09E+10	6.82E+09	89%
VAR040095	Nova Manassas Campus				
VAR040062	VDOT Urban Area				
VAR040070	City of Manassas Park	City of Manassas Park	3.16E+10	3.55E+09	89%
VAR040062	VDOT Urban Area				
VA0088595	Prince William County	Prince William County	1.43E+11	1.60E+10	89%
VAR040100	Prince William County Schools				
VAR040062	VDOT Urban Area				
Total			**1.03E+12**	**1.16E+11**	89%

5.12.2 Bull Run (VAN-A23R-01) Allocation Plan

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Bull Run are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 90% reduction of bacteria loading from agricultural and urban nonpoint sources.
- No reductions from the forested land (wildlife indirect loads).
- 89% reduction of bacteria loading from MS4 locations, reflecting weighted average of the reductions required from forest (0%) and urban land (90%)

Table 5-26 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-26: Bull Run VAN-A23R-01 Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation (Excluding MS4s from the Land-based Loads)

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)
	Existing	Allocation	
Forest	1.42E+10	1.42E+10	0.0%
Cropland	7.97E+07	7.97E+06	90.0%
Pasture	3.19E+09	3.19E+08	90.0%
Low Density Residential	5.83E+11	5.83E+10	90.0%
Commercial/Industrial	2.58E+10	2.58E+09	90.0%
Water/Wetland	6.49E+08	6.49E+08	0.0%
Other Urban	8.98E+09	8.98E+08	90.0%
High Density Residential	4.66E+11	4.66E+10	90.0%
Cattle - direct deposition	8.93E+12	0.00E+00	100.0%
Wildlife - direct deposition	4.88E+12	8.30E+11	83.0%
Failed Septic - direct deposition	2.91E+10	0.00E+00	100.0%
Point Source	1.11E+14	1.11E+14	-
MS4s	1.03E+12	1.16E+11	88.8%
Total loads /Overall reduction	**1.27E+14**	**1.12E+14**	-

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-15** and **Figure 5-16. Figure 5-15** shows the calendar month geometric mean *E. coli* concentrations, as well as geometric mean concentrations under existing conditions**. Figure 5-16** shows the instantaneous *E. coli* concentrations under the allocations, as well as the concentrations under existing conditions. For Bull Run (Segment VAN-A23R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Bull Run is presented in **Table 5-27**.

Table 5-27: Bull Run Segment VAN-A23R-01 TMDL Allocation Plan Loads (cfu/year) for *E. coli*			
WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
1.11E+14	9.54E+11	IMPLICIT	1.12E+14

(*) includes the MS4 allocations

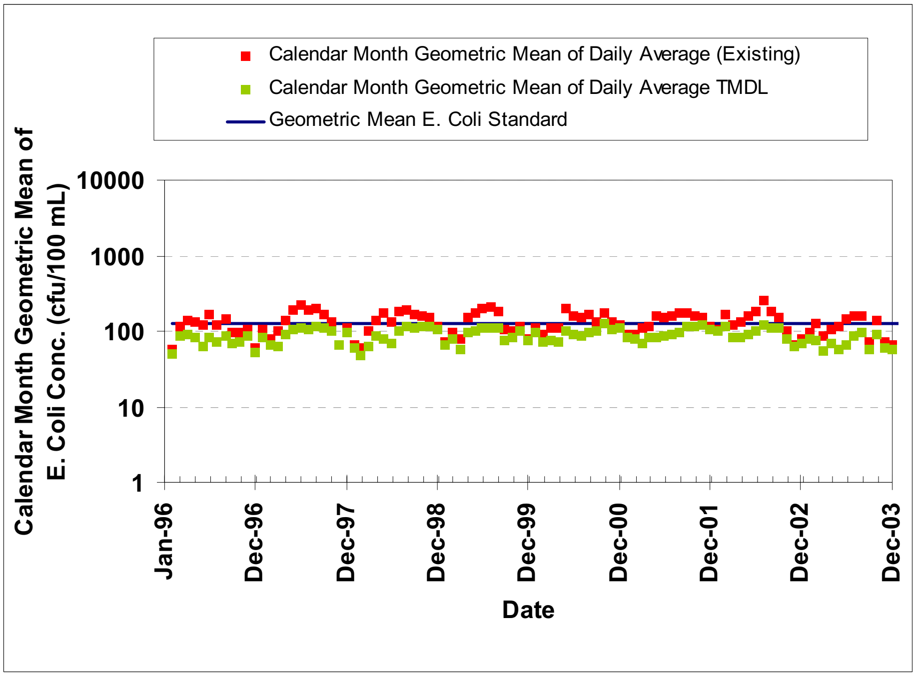

Figure 5-15: Bull Run Segment VAN-A23R-01 Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

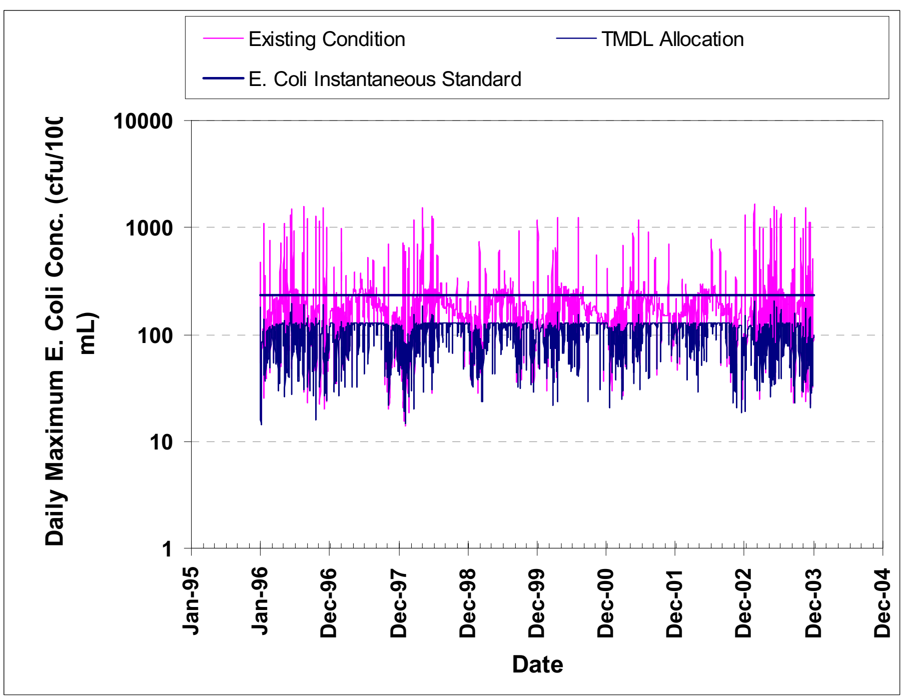

Figure 5-16: Bull Run Segment VAN-A23R-01 Instantaneous E. coli Concentrations under Existing Conditions and the Allocation Scenario

5.13 Occoquan River (Segment VAN-A20R-01) TMDL

5.13.1 Occoquan River (VAN-A20R-01) Waste Load Allocation

There are no individual municipal VPDES permitted facilities currently discharging into the Occoquan River (Segment VAN-A20R-01). However, there are eight general permitted facilities discharging into this watershed (**Table 5-28**). The waste load allocation for this subwatershed was computed based on the design flow for each facility as listed in **Table 3-16**, with an expansion factor of five times the design flow included in the computation. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed and applied based on the discretion of DEQ staff.

Table 5-28: Occoquan River (Segment VAN-A20R-01) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAG406278	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406254	Domestic Sewage Discharge	1.74E+09	2.61E+09	-
VAG406327	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406078	Domestic Sewage Discharge	1.74E+09	3.48E+09	-
VAG406220	Domestic Sewage Discharge	1.74E+09	8.71E+08	-
VAG406237	Domestic Sewage Discharge	1.74E+09	5.22E+09	-
VAG406255	Domestic Sewage Discharge	1.74E+09	3.92E+09	-
VAG406256	Domestic Sewage Discharge	1.74E+09	4.35E+09	-
Total		**1.39E+10**	**2.83E+10**	**-**

Within the Occoquan River (segment VAN-A20R-01) there are four (4) MS4s permits requiring TMDL allocations. **Table 5-29** shows the waste load allocations for each MS4. The waste load allocations were based on each municipality's share of the contributing urbanized area of the impairment.

Table 5-29: Occoquan River (Segment VAN-A20R-01) MS4s Waste load Allocation for *E. coli*

Permit Number	MS4 Permit Holder	Area	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Reduction (%)
VAR040063	City of Manassas	City of Manassas	4.66E+11	2.95E+10	94%
VAR040062	VDOT Urban Area				
VA0088595	Prince William County	Prince William County	2.72E+12	1.72E+11	94%
VAR040100	Prince William County Schools				
VAR040062	VDOT Urban Area				
Total			**3.18E+12**	**2.01E+11**	**94%**

5.13.2 Occoquan River (VAN-A20R-01) Allocation Plan

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for the Occoquan River are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- No reductions from the forested land (wildlife indirect loads).
- 94% reduction of bacteria loading from MS4 locations, reflecting weighted average of the reductions required from forest (0%) and urban land (95%).

Table 5-30 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix I.

Table 5-30: Occoquan River VAN-A20R-01 Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation (Excluding MS4s from the Land-based Loads)

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)
	Existing	Allocation	
Forest	3.70E+09	3.70E+09	0%
Cropland	7.63E+08	3.81E+07	95%
Pasture	1.57E+09	7.84E+07	95%
Low Density Residential	1.27E+11	6.37E+09	95%
Commercial/Industrial	1.70E+10	8.48E+08	95%
Water/Wetland	1.13E+08	1.13E+08	0%
Other Urban	2.86E+09	1.43E+08	95%
High Density Residential	1.12E+11	5.59E+09	95%
Cattle - direct deposition	6.91E+10	0.00E+00	100%
Wildlife - direct deposition	3.56E+11	3.56E+11	0%
Failed Septic - direct deposition	5.26E+09	0.00E+00	100%
Point Source	1.39E+10	2.83E+10	-
MS4s	3.15E+12	2.01E+11	94%
Total loads /Overall reduction	**3.89E+12**	**6.01E+11**	-

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-17** and **Figure 5-18. Figure 5-17** shows the calendar month geometric mean *E. coli* concentrations, as well as geometric mean loading under existing conditions**. Figure 5-18** shows the instantaneous *E. coli* concentrations under the allocations, as well as the concentrations under existing conditions. For the Occoquan River (Segment VAN-A20R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for the Occoquan River is presented in **Table 5-31**.

Table 5-31: Occoquan River Segment TMDL Allocation Plan Loads (cfu/year) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
2.29E+11*	3.73E+11	IMPLICIT	6.01E+11

(*) includes the MS4 allocations

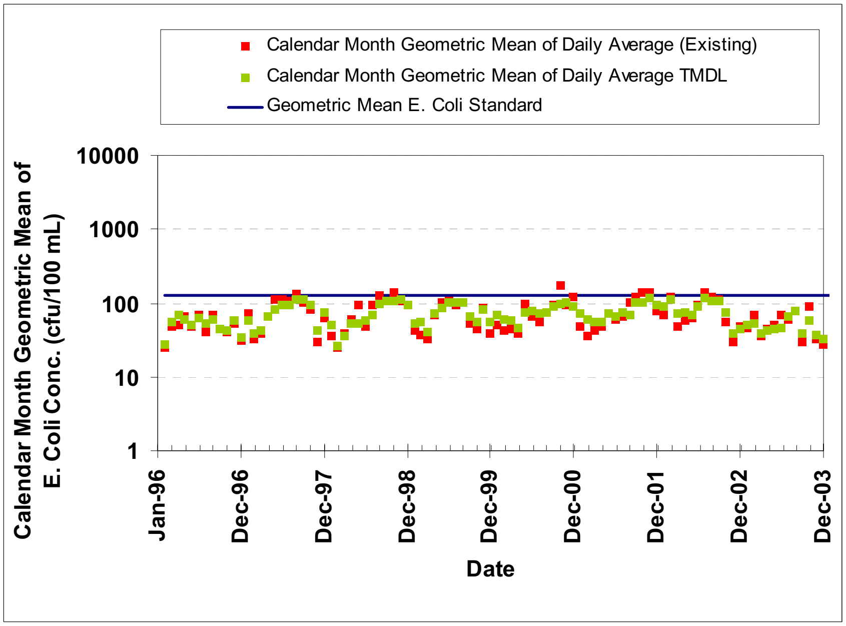

Figure 5-17: Occoquan River Segment VAN-A20R-01 Geometric Mean E. coli Concentrations under Existing Conditions and the Allocation Scenario

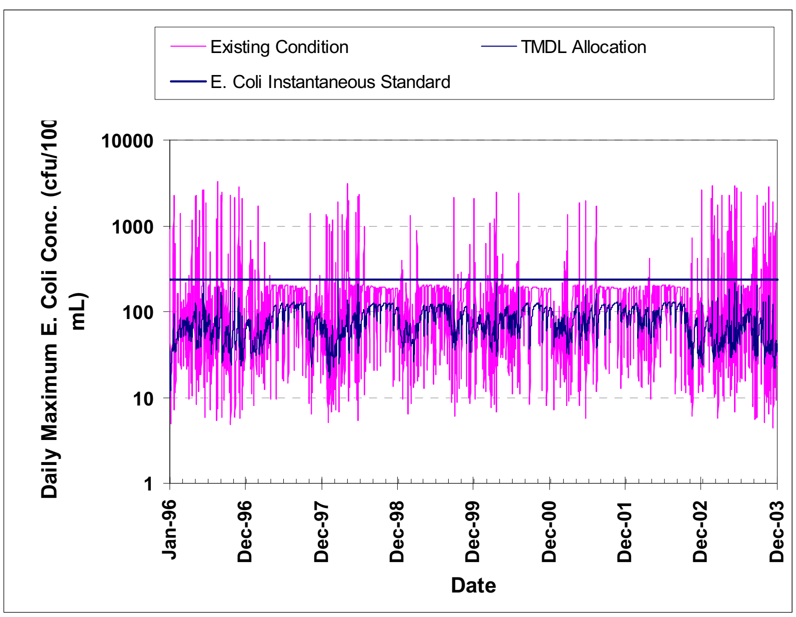

Figure 5-18 Occoquan River Segment VAN-A20R-01 Instantaneous E. coli Concentrations under Existing Conditions and the Allocation Scenario

6.0 TMDL Implementation

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 7.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR '122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

6.1 Staged Implementation

In general, Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2 Stage 1 Scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios. It was estimated for modeling purposes that there are 17 straight pipes in the watershed. Should any be found during the implementation process, they should be eliminated as soon as possible since they would be illegally discharging fecal bacteria into Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River and their tributaries.

Three allocation scenarios are presented in **Tables 6-1 to 6-9** for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River respectively. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table 6-1: Broad Run (VAN A19R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	90	90	0	0%	10%
2	100	50	50	50	0	3%	23%
3	100	75	75	75	0	0%	7%

Table 6-2: Broad Run (VAN A19R-02) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	90	90	0	0%	10%
2	100	50	50	50	0	38%	90%
3	100	75	75	75	0	31%	87%

Table 6-3: Broad Run (VAN A19R-05) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	90	90	0	0%	10%
2	100	50	50	50	0	30%	87%
3	100	75	75	75	0	26%	84%

Table 6-4: South Run Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	96	70	55	0%	10%
2	100	50	50	50	0	0%	27%
3	100	75	75	75	0	0%	23%

Table 6-5: Kettle Run Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	90	90	0	0%	10%
2	100	50	50	50	0	40%	94%
3	100	75	75	75	0	26%	90%

Table 6-6: Popes Head Creek Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	90	90	50	0%	10%
2	100	50	50	50	0	13%	74%
3	100	75	75	75	0	11%	52%

Table 6-7: Little Bull Run Watershed Stage 1 Scenarios							
Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	85	85	0	0%	10%
2	100	50	50	50	0	1%	23%
3	100	75	75	75	0	0%	14%

Table 6-8: Bull Run Watershed Stage 1 Scenarios							
Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	90	90	0	0%	10%
2	100	50	50	50	0	0%	23%
3	100	75	75	75	0	0%	18%

Table 6-9: Occoquan River Watershed Stage 1 Scenarios							
Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100	100	95	95	0	0%	10%
2	100	50	50	50	0	0%	20%
3	100	75	75	75	0	0%	16%

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of the Tributary Strategy for the Potomac River basin. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms. Up-to-date information on the tributary strategy implementation process can be found at the tributary strategy web site under http://www.snr.state.va.us/Initiatives/TributaryStrategies/.cfm.

Fairfax County is in the process of developing watershed management plans countywide. The plans are being developed with the help of citizens' advisory committees and other public input, and they will lay out the county's strategy for improving stormwater management over the next 25 years. While the plans do not explicitly address the bacteria impairments described in this report, it is anticipated that many of the actions to control stormwater and reduce pollutant loads that are proposed in the plans will also help reach water quality goals for bacteria set by existing and future TMDLs. The relevant projects and recommendations made in the county's watershed management plans will be considered during the implementation planning process for this TMDL and incorporated as appropriate.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens', watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.4.3 Stormwater Permits

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:…(2) Numeric effluent limitations are infeasible,…".

Part of the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds are covered by permits for the small municipal separate storm sewer systems (MS4s). Phase I MS4 operators include Fairfax County and Prince William County. Phase II MS4 entities include: Loudoun County; the City of Manassas; the City of Manassas Park; the City of Fairfax; MWAA Washington Dulles International Airport; Prince William County Schools; Fairfax County Schools; Northern Virginia Community College (Manassas Campus); Virginia Department of Transportation, Northern Virginia Urban Area. The permits state, under Part II.A., that the "permittee must develop, implement, and enforce a stormwater management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP), to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act and the State Water Control Law."

The permit also contains a TMDL clause that states: "If a TMDL is approved for any waterbody into which the small MS4 discharges, the Board will review the TMDL to determine whether the TMDL includes requirements for control of stormwater discharges. If discharges from the MS4 are not meeting the TMDL allocations, the Board will notify the permittee of that finding and may require that the Stormwater

Management Program required in Part II be modified to implement the TMDL within a timeframe consistent with the TMDL."

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. DEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 7.4.5 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards change on Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run or the Occoquan River would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/stormwat.htm.

6.4.4 Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5 Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load. V**irginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. Additionally, other factors may prevent the stream from attaining the primary contact recreation use.

To address this issue, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at http://www.deq.virginia.gov/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/WQS03AUG.pdf

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 6-2 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

7.0 Public Participation

The development of the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River bacteria TMDLs would not have been possible without public participation. Three technical advisory committee (TAC) meetings and three public meetings were held within the watershed. The following is a summary of the meetings.

TAC Meeting No. 1: The first TAC meeting was held on March 1, 2005 at the DEQ office in Woodbridge to present and review the steps and the data used in the development of the bacteria TMDLs for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River listed segments.

TAC Meeting No. 2: The second TAC meeting was held on November 3, 2005 at the DEQ office in Woodbridge, VA to discuss the preliminary source assessment for the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River watersheds.

TAC Meeting No. 3: The third TAC meeting was held on March 1, 2006 at the DEQ office in Woodbridge VA to discuss the completed TMDLs for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River's bacteria impairments.

Public Meeting No. 1: The first public meetings were held in on March 30, 2005 at the Sully District Governmental Center in Chantilly, Virginia and on April 5, 2005 at the Pennington School in Manassas, Virginia to present the process for TMDL development, the Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River bacteria impaired segments, data that caused the segments to be on the 303(d) list and identify data and information needed for TMDL development. Nineteen people added these meetings. Copies of the presentation were available for public distribution. This meeting was publicly noticed in the *Virginia Register*. No written comments were received during the 30-day comment period.

Public Meeting No. 2: The second public meeting was held on December 14, 2005 at the Sully District Governmental Center in Chantilly, Virginia to discuss the preliminary bacteria sources identified for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River. Six people attended this meeting. Copies of the presentation and the draft TMDL report executive summary were available for public distribution. The meeting was public noticed in *The Virginia Register of Regulations.*

Public Meeting No. 3: The third public meeting on the development of the bacteria TMDLs for Broad Run, Kettle Run, South Run, Popes Head Creek, Little Bull Run, Bull Run and the Occoquan River Watersheds was held on March 15, 2006 at the Central Community Library in Manassas, VA to discuss the Draft TMDL. Copies of the presentation were available for public distribution. Ten people attended this meeting. The meeting was public noticed in *The Virginia Register of Regulations.*

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Soil Environmental Sciences of the Virginia Polytechnic Institute and State University, Blacksburg VA.

APPENDIX A:
Discharge Monitoring Report Data

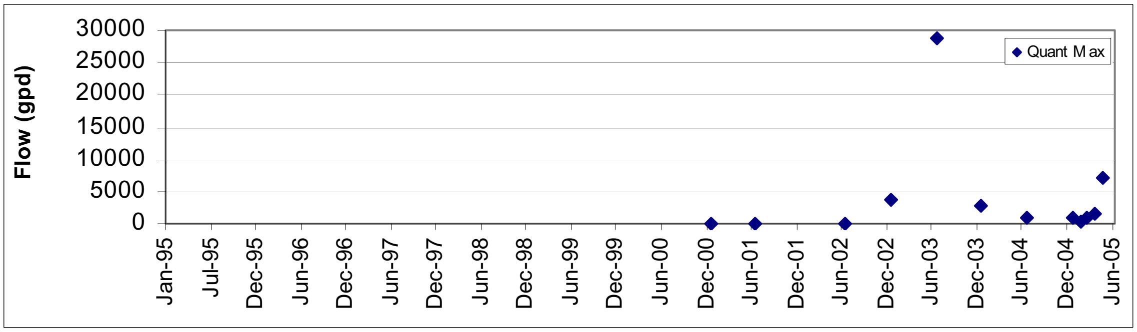


Figure A-1: Adaptive Concrete Flow Outfall 1

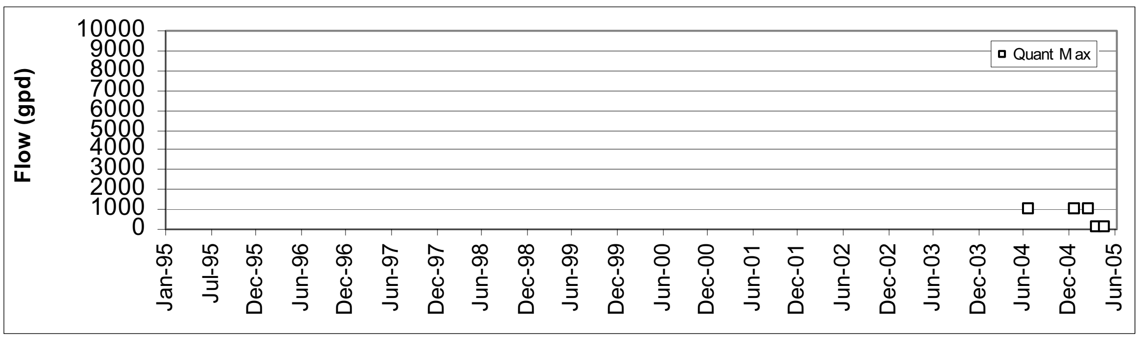


Figure A-2: Adaptive Concrete Flow Outfall 2

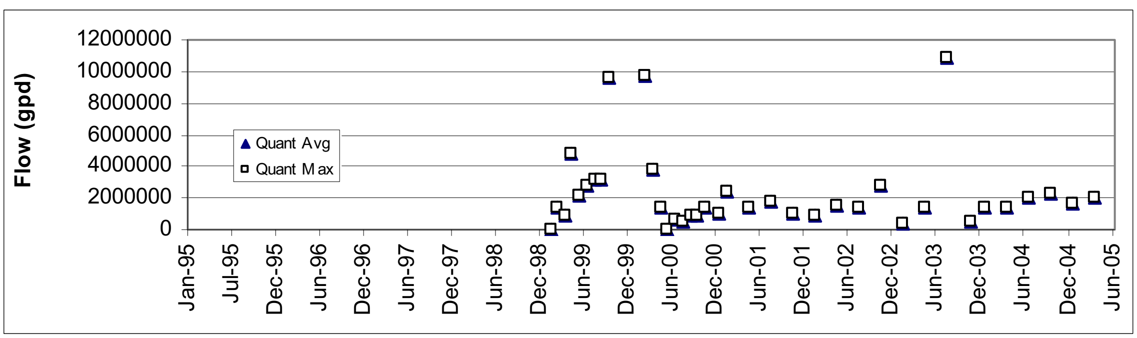


Figure A-3: Atlantic Research Flow Outfall 1

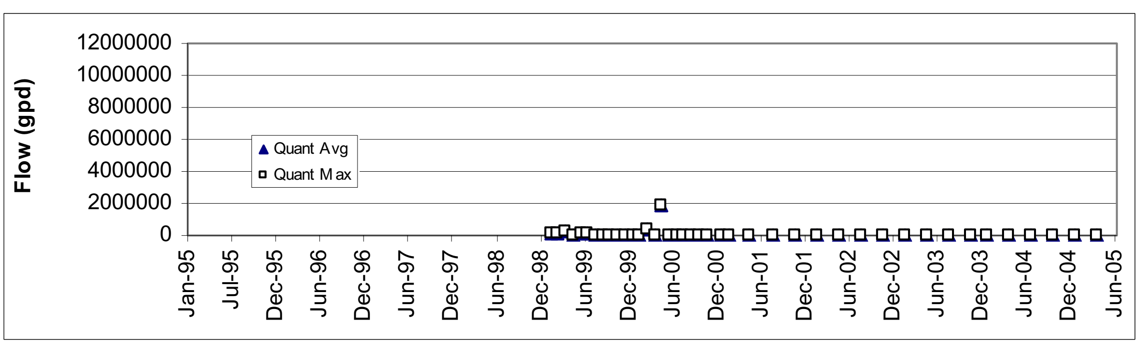


Figure A-4: Atlantic Research Flow Outfall 2

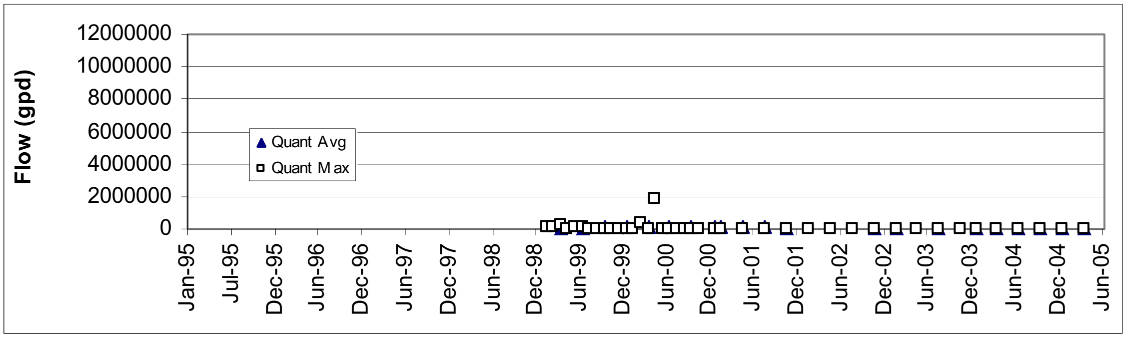


Figure A-5: Atlantic Research Flow Outfall 101

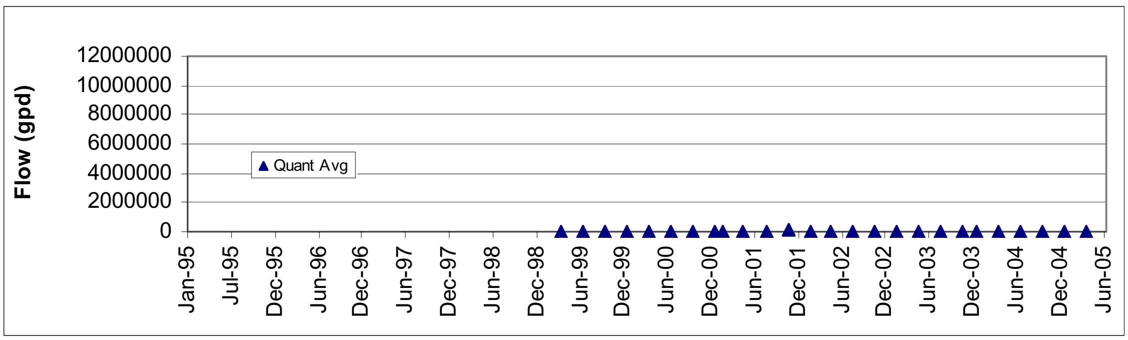


Figure A-6: Atlantic Research Flow Outfall 102

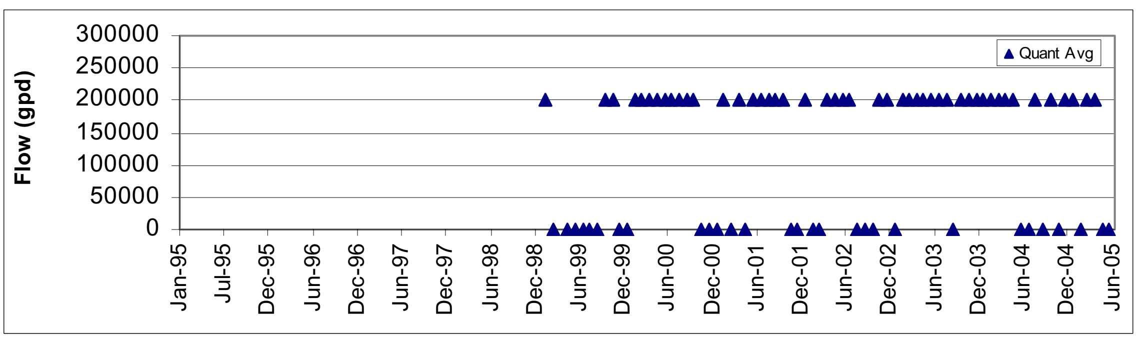


Figure A-7: Balls Ford Composting Flow Outfall 1

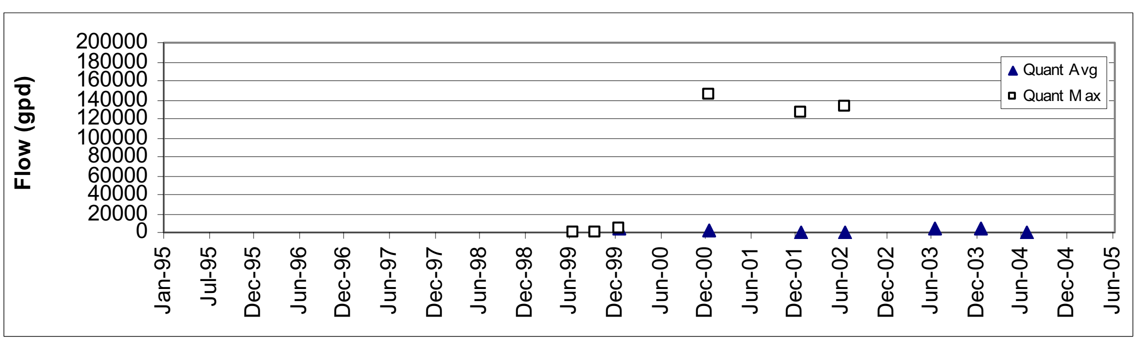


Figure A-8: Colonial Pipeline Flow Outfall 1

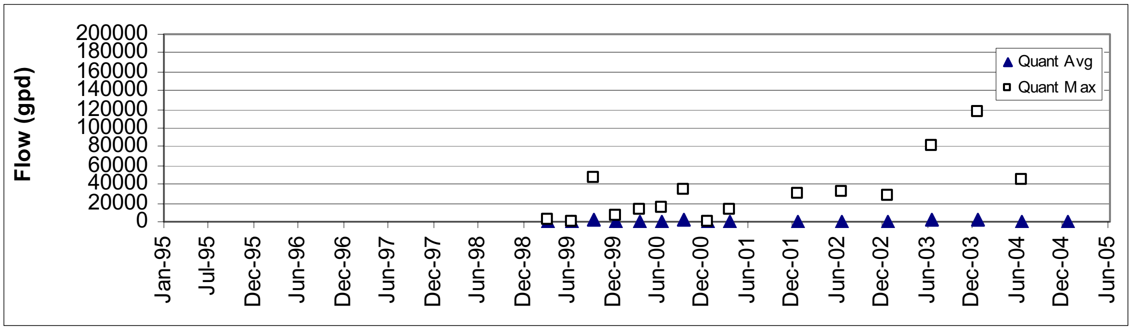


Figure A-9: Colonial Pipeline Flow Outfall 2

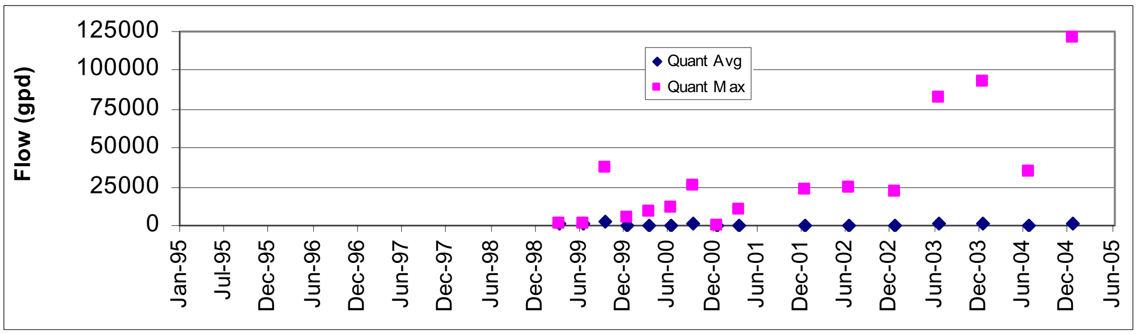


Figure A-10: Colonial Pipeline Bull Run Flow Outfall 1

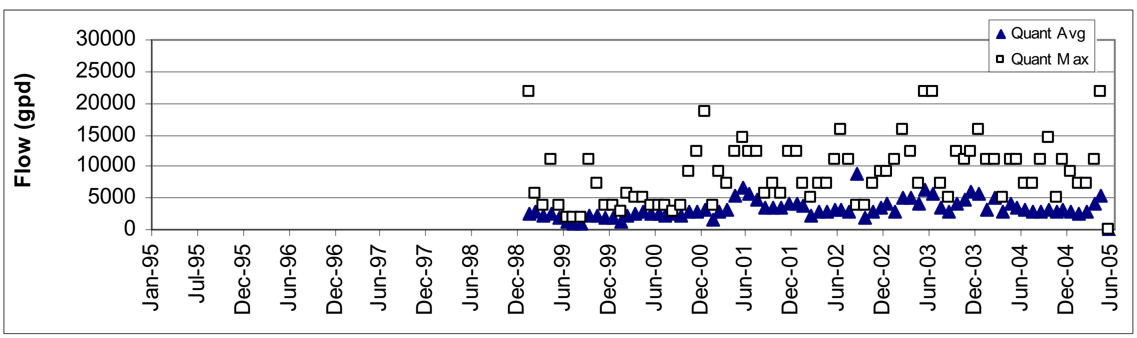


Figure A-11: Evergreen Country Club Flow Outfall 1

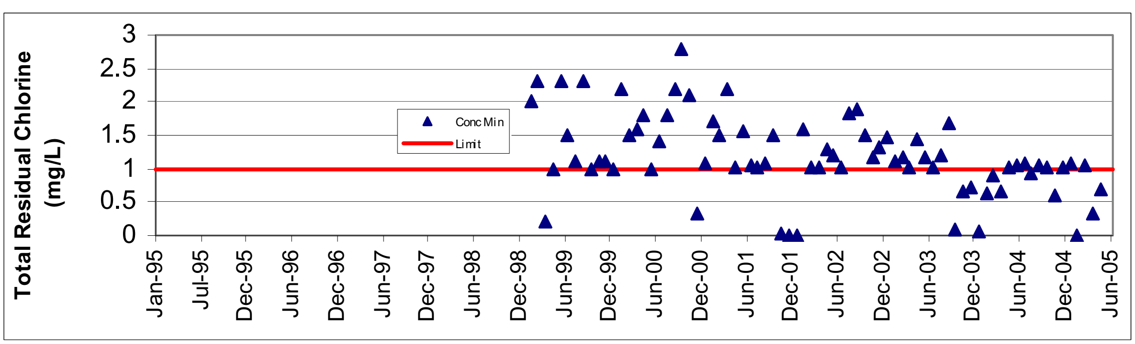


Figure A-12: Evergreen Country Club Total Residual Chlorine Outfall 1

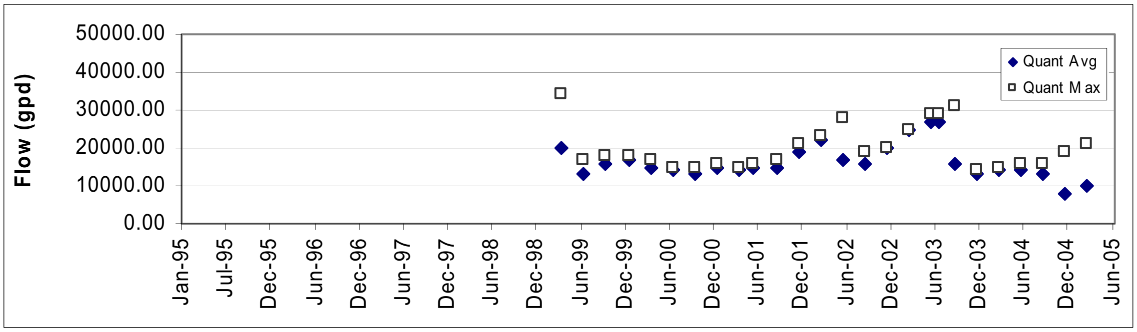


Figure A-13: IBM Corporation Flow Values from Outfall 1

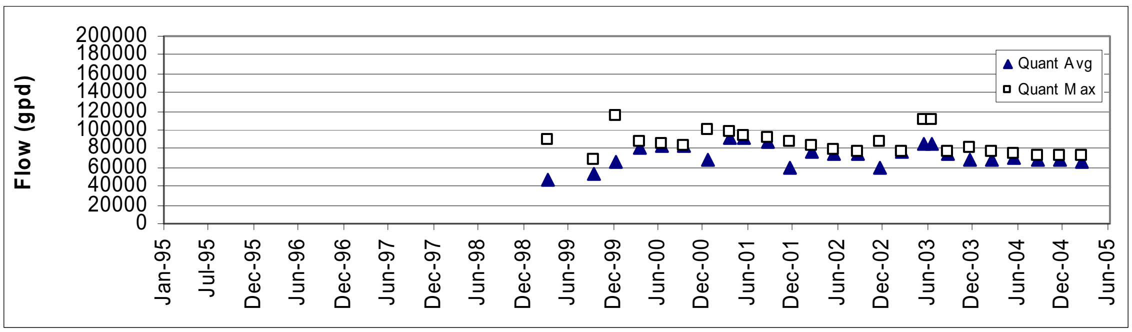


Figure A-14: IBM Corporation Flow Values from Outfall 2

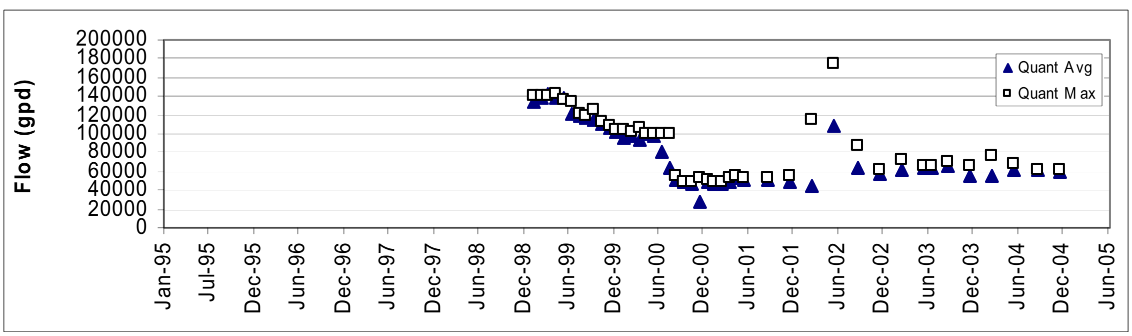


Figure A-15: IBM Corporation Flow Values from Outfall 3

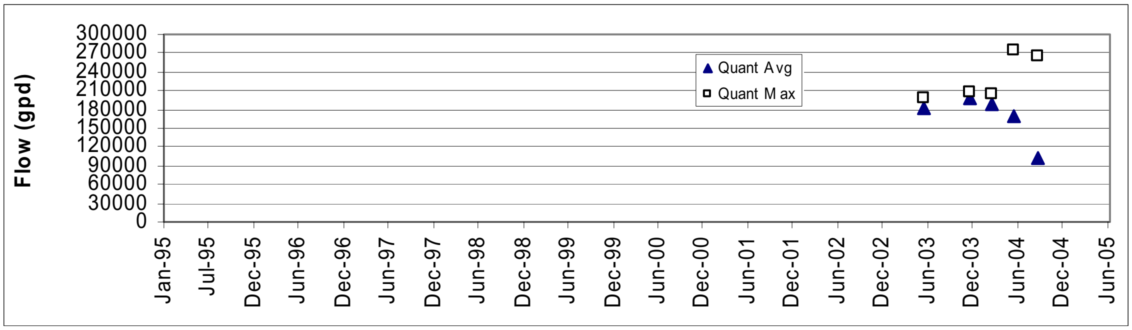


Figure A-16: IBM Corporation Flow Values from Outfall 4

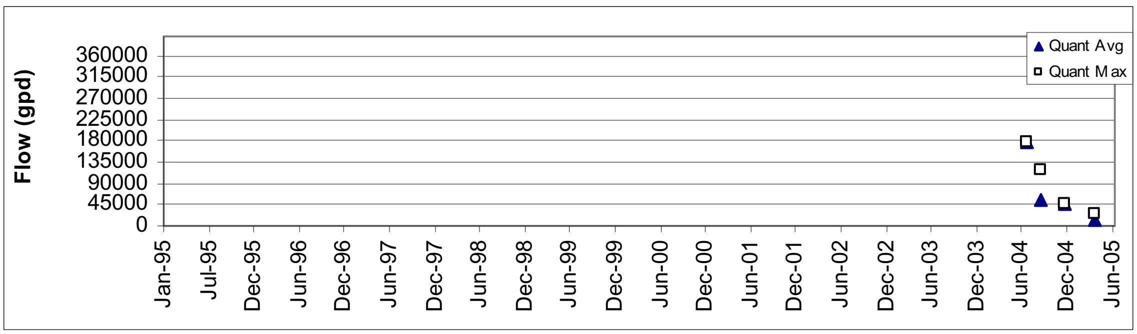


Figure A-17: Loudoun Composting Flow Outfall 1

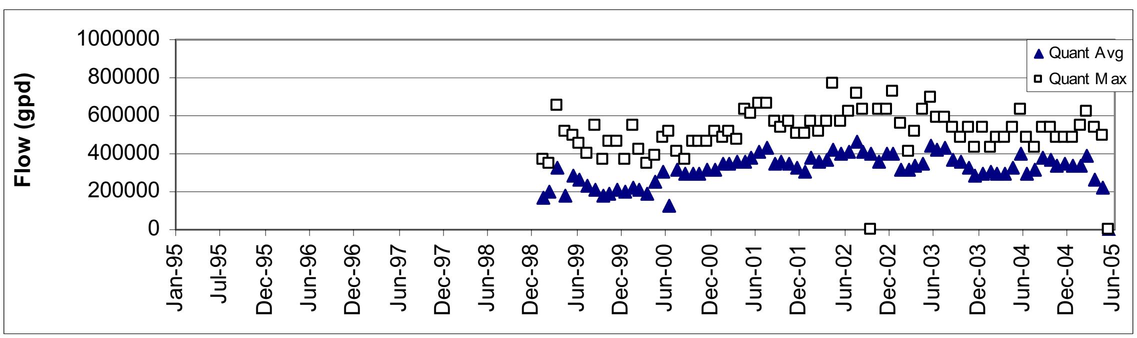


Figure A-18: Manassas City Flow Outfall 1

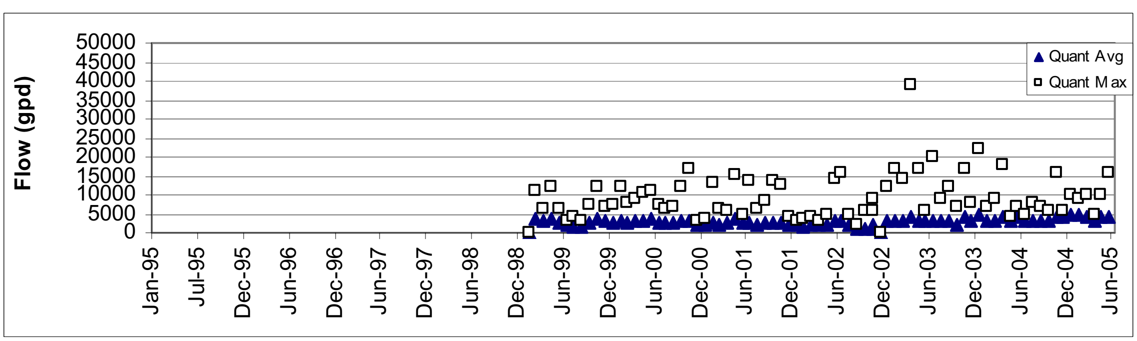


Figure A-19: New Baltimore Shell Flow Outfall 1

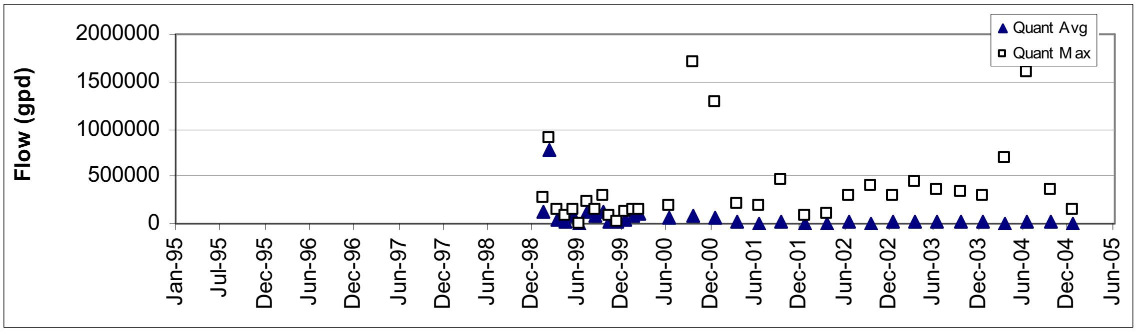


Figure A-20: Sunoco Manassas Flow Outfall 1

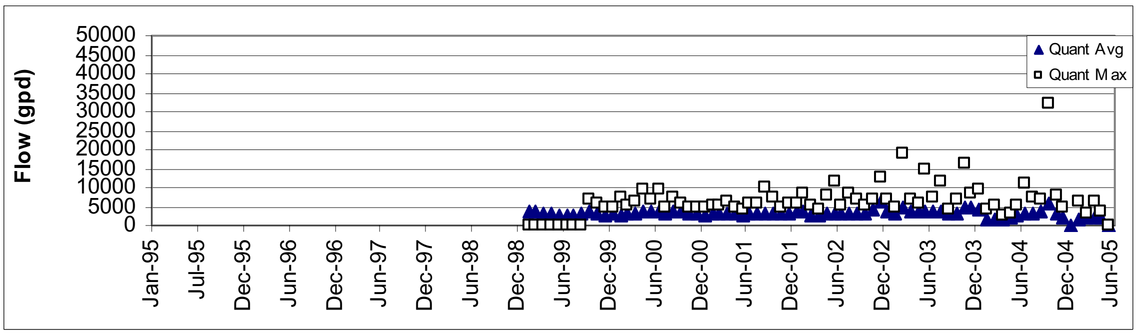


Figure A-21: Town & Country Flow Outfall 1

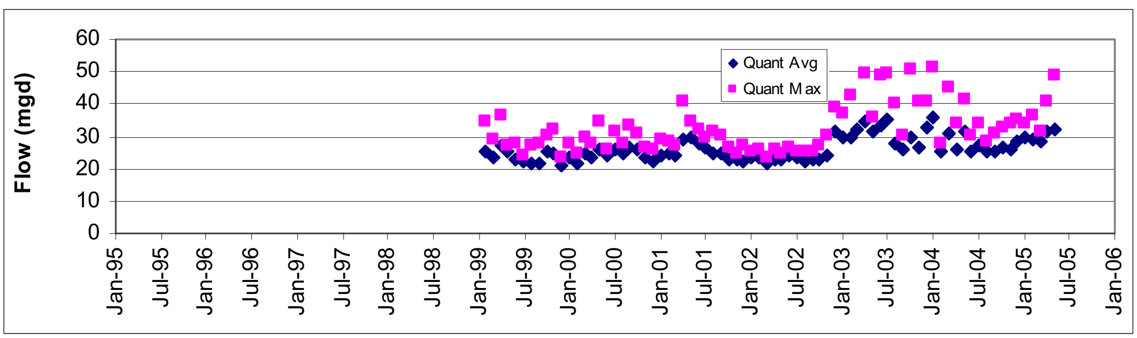


Figure A-22: UOSA Flow Outfall 1

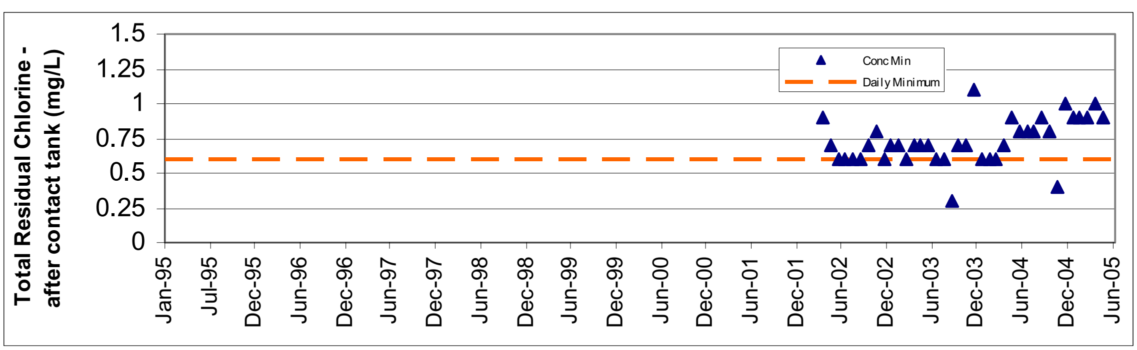


Figure A-23: UOSA Total Residual Chlorine Outfall 1

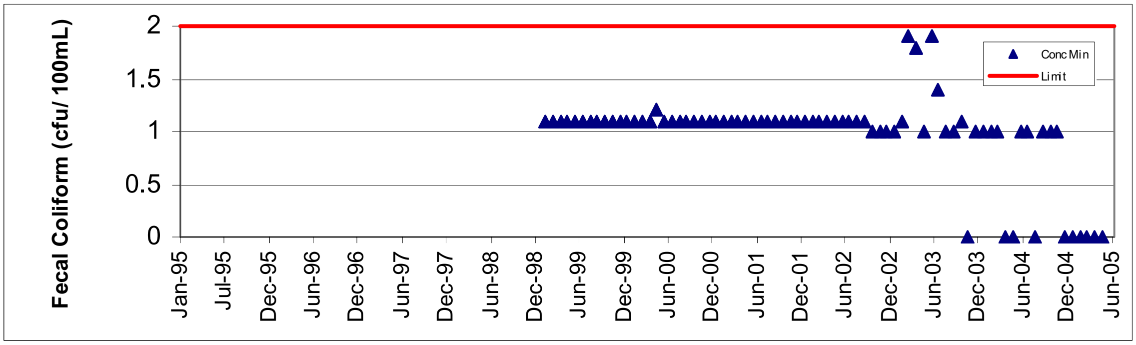


Figure A-24: UOSA Fecal Coliform Outfall 1

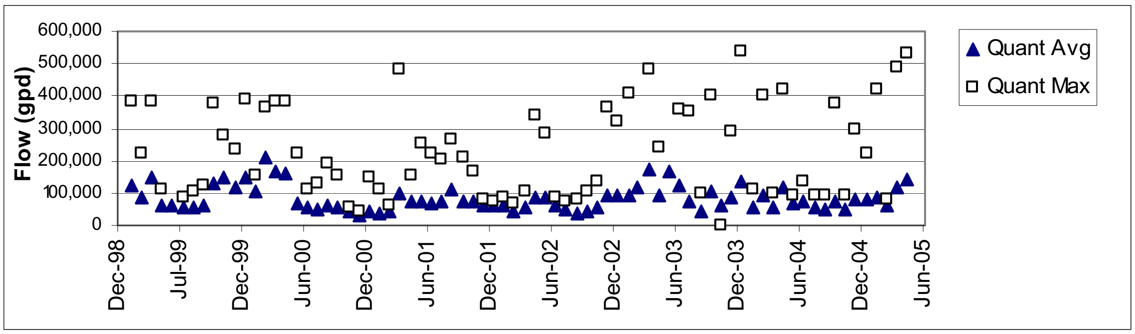


Figure A-25: Vint Hills DMR Flow

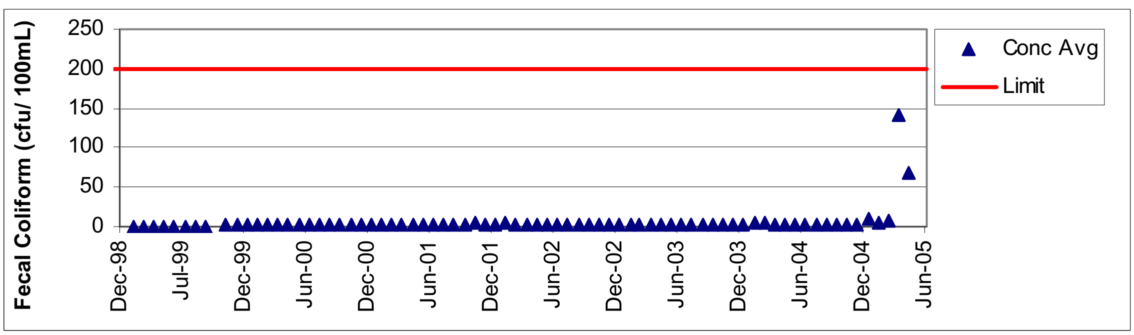


Figure A-26: Vint Hills Fecal Coliform

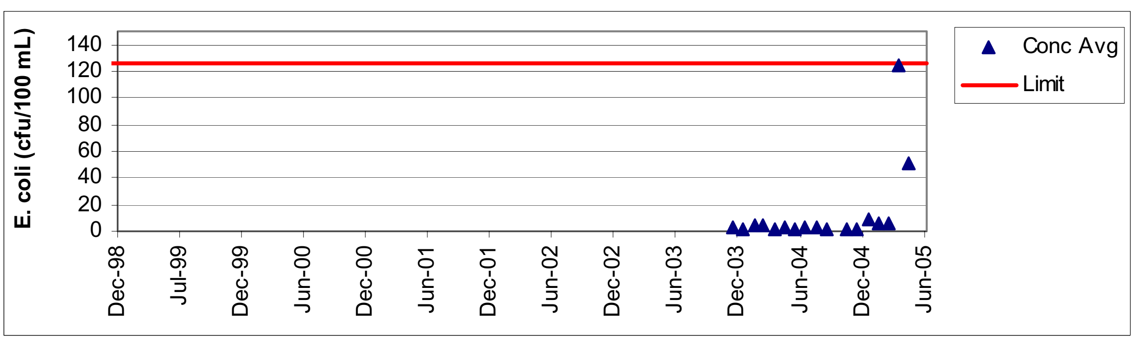


Figure A-27: Vint Hills E. Coli

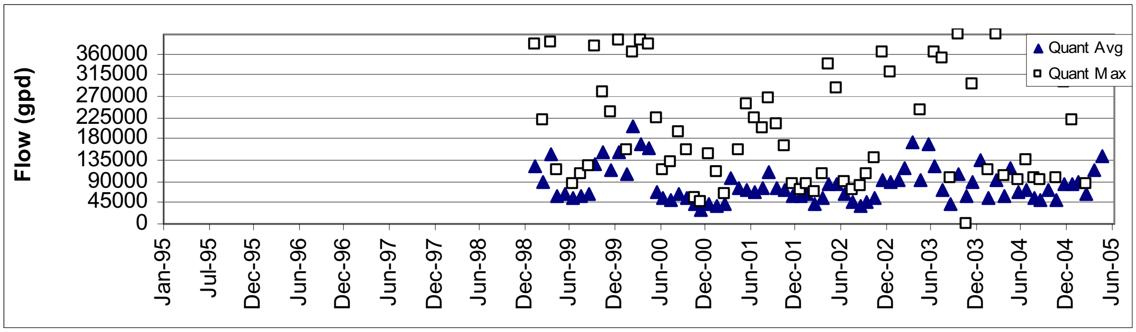


Figure A-28: Woodbridge MHP Flow

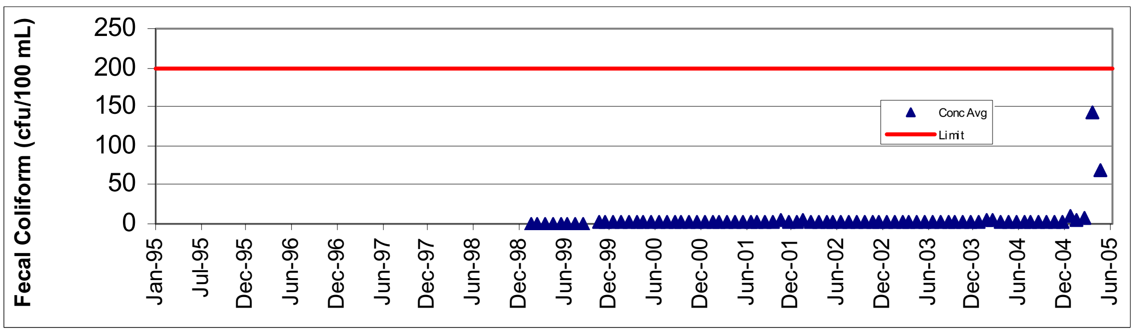


Figure A-29: Woodbridge MHP Fecal Coliform

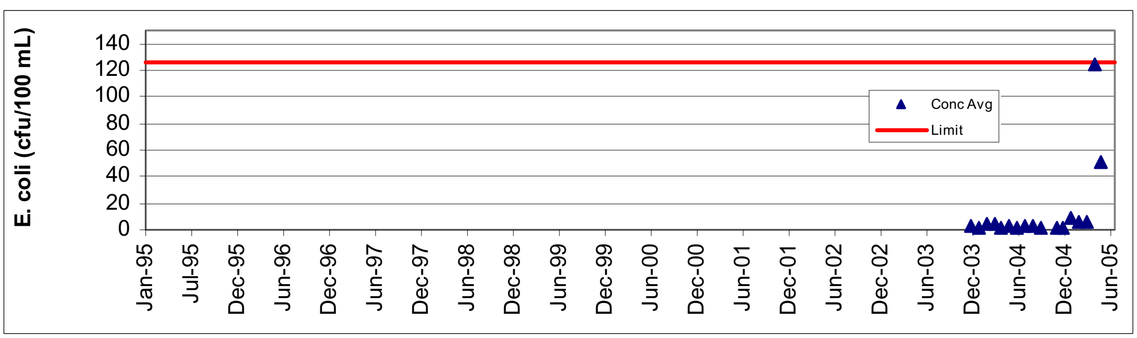


Figure A-30: Woodbridge MHP E. Coli

APPENDIX B: Livestock and Wildlife Inventories by Subwatershed

Table B-1: Livestock Inventory by Subwatershed:

Subshed ID	Beef cows	Milk cows	Hogs and pigs inventory	Sheep and lambs inventory	Layers 20 weeks old and older inventory	Horses and ponies, inventory	Alpacas
1	0	0	0	0	0	0	0
2	22	8	2	3	14	81	0
3	3	0	0	1	3	19	0
4	11	6	0	1	4	21	0
5	0	0	0	0	0	0	0
6	1	0	0	0	1	5	0
7	6	0	1	2	7	40	0
8	4	0	1	1	4	23	0
9	11	4	1	2	7	42	0
10	2	0	0	1	2	13	0
11	0	0	0	0	0	2	0
12	6	0	1	2	6	37	0
13	1	0	0	0	1	4	0
14	2	0	0	0	2	10	0
15	1	0	0	0	1	4	0
16	52	1	4	12	28	181	0
17	100	0	0	0	0	150	0
18	100	0	0	0	0	175	0
19	181	44	3	26	38	250	0
20	150	0	0	0	0	150	0
21	200	0	0	0	0	175	0
22	100	0	0	0	0	150	0
23	50	0	0	0	0	50	0
24	50	0	0	0	0	50	0
25	150	0	0	0	0	150	0
26	100	0	0	0	0	150	0
27	98	56	1	5	35	164	0
28	4	2	0	0	1	7	0
29	4	2	0	0	2	7	0
30	0	0	0	0	0	10	0
31	0	0	0	0	0	25	0
32	6	4	0	0	2	11	0
33	0	0	0	0	0	75	0
34	150	0	0	0	0	200	25
35	150	0	0	0	0	200	25
36	150	0	0	0	0	200	20
37	100	0	0	0	0	100	200
38	80	45	1	4	28	134	0
39	84	40	1	4	23	115	0
40	0	0	0	0	0	25	0
41	35	0	0	0	0	103	0
42	50	0	0	0	0	0	0

Subshed ID	Beef cows	Milk cows	Hogs and pigs inventory	Sheep and lambs inventory	Layers 20 weeks old and older inventory	Horses and ponies, inventory	Alpacas
43	245	0	0	0	0	26	0
44	417	0	0	0	100	227	0
45	825	225	12	37	85	589	0
46	333	91	5	15	34	238	0
47	45	0	0	0	0	36	0
48	0	0	0	0	0	37	0
49	50	0	0	0	0	100	0
50	50	0	0	0	0	100	0
51	100	650	0	0	0	200	0
52	29	0	0	10	0	37	0
Totals	**4,307**	**1,180**	**34**	**127**	**430**	**4,896**	**270**

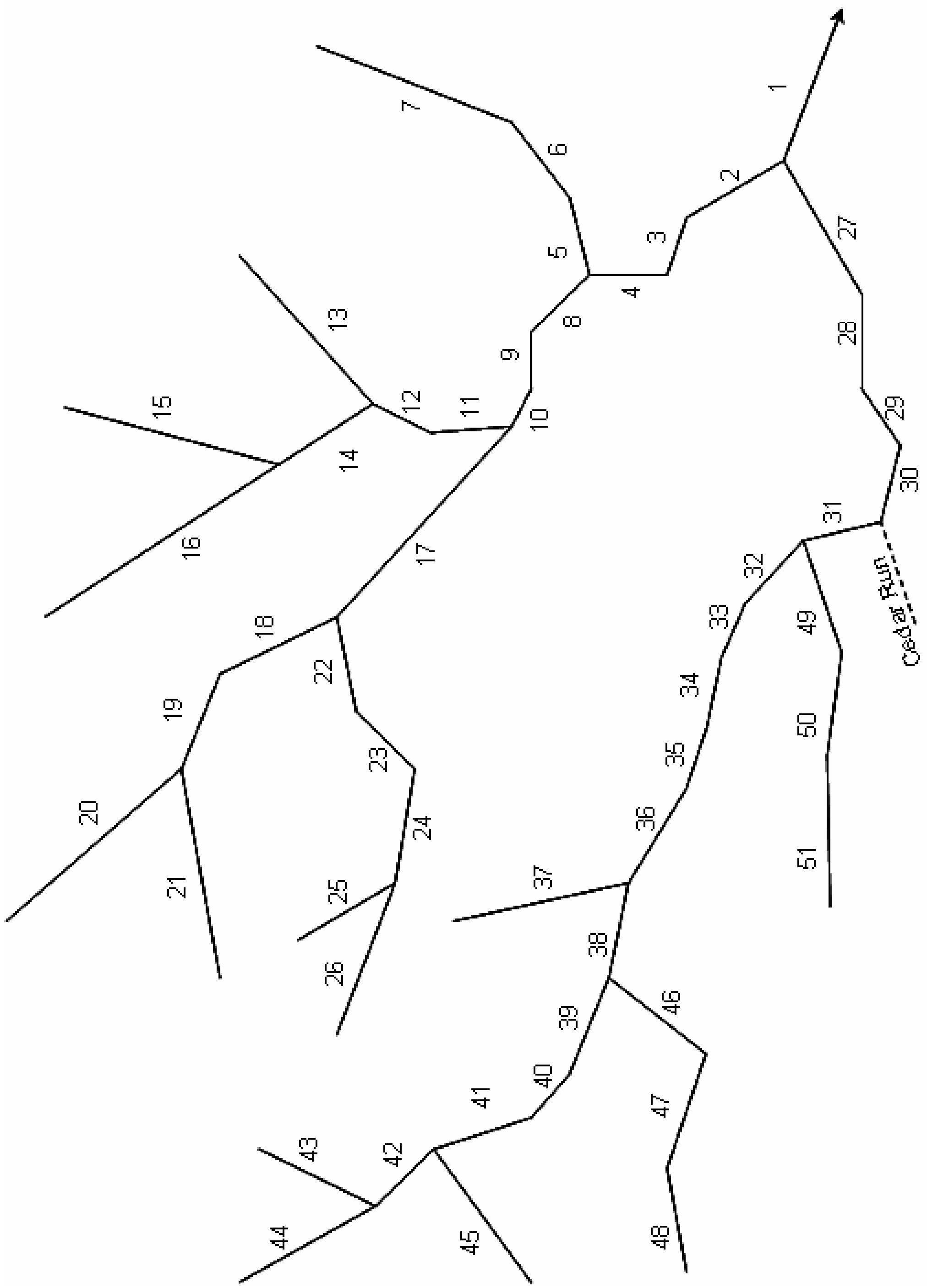
Table B-2: Wildlife Inventory

Subshed ID	Deer	Raccoon	Muskrat	Beaver	Wild Turkey	Goose	Mallard	Wood Duck
1	1053	675	2917	318	90	448	45	2
2	127	531	2297	251	15	54	5	2
3	139	61	262	29	18	59	6	0
4	17	98	425	46	3	7	1	0
5	53	53	227	25	5	23	2	0
6	170	162	702	77	12	72	7	0
7	347	307	1327	145	33	148	15	1
8	543	324	1402	153	57	231	23	1
9	42	90	388	42	4	18	2	0
10	12	9	39	4	0	5	1	0
11	78	55	239	26	15	33	3	0
12	19	9	39	4	0	8	1	0
13	282	195	843	92	25	120	12	1
14	140	94	406	44	0	60	6	0
15	701	671	2901	316	95	298	30	2
16	348	149	643	70	57	148	15	0
17	831	868	3750	409	101	354	35	2
18	375	205	888	97	66	159	16	1
19	84	259	1119	122	17	36	4	1
20	335	288	1245	136	62	142	14	1
21	352	361	1562	170	63	150	15	1
22	164	173	747	81	24	70	7	0
23	53	57	248	27	10	23	2	0
24	55	46	197	21	11	24	2	0
25	288	244	1053	115	53	123	12	1
26	265	214	923	101	51	113	11	1
27	167	157	677	74	20	71	7	0
28	244	238	1029	112	27	104	10	1

Subshed ID	Deer	Raccoon	Muskrat	Beaver	Wild Turkey	Goose	Mallard	Wood Duck
29	186	157	676	74	19	79	8	0
30	270	233	1007	110	27	115	11	1
31	59	58	252	27	0	25	3	0
32	308	260	1122	122	40	131	13	1
33	90	71	309	34	11	38	4	0
34	232	208	899	98	35	99	10	1
35	268	222	959	105	44	114	11	1
36	202	209	905	99	34	86	9	1
37	253	172	742	81	43	108	11	0
38	198	155	671	73	37	84	8	0
39	24	9	39	4	4	10	1	0
40	51	53	230	25	8	22	2	0
41	362	96	416	45	69	154	15	0
42	21	184	797	87	4	9	1	1
43	237	12	50	5	50	101	10	0
44	592	156	674	74	120	252	25	0
45	285	445	1924	210	58	121	12	1
46	1	2	10	1	0	0	0	0
47	55	241	1040	113	10	23	2	1
48	147	31	133	14	20	62	6	0
49	28	39	167	18	5	12	1	0
50	57	57	245	27	11	24	2	0
51	372	535	2311	252	61	158	16	2
52	324	56	244	27	49	138	14	0
Total	**11,908**	**10,255**	**44,316**	**4,834**	**1,695**	**5,067**	**507**	**29**

Appendix C

Model Representation of Stream Reach Networks



Model representation of Occoquan River Model
Stream Network

Appendix D

Monthly Fecal Coliform Build-up Rates

Table D-1: Monthly Build-up Rates cfu/ac/day (January to June)						
Land use	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Forest	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07
Cropland	3.30E+08	8.40E+08	4.80E+08	9.90E+08	5.20E+08	1.90E+07
Pasture	1.30E+09	1.40E+09	1.30E+09	1.40E+09	1.30E+09	1.20E+09
Low Intensity Residential	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09
Commercial/Industrial /Transportation	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08
Other Urban	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08
High Intensity Residential	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09

Table D-2: Monthly Build-up Rates cfu/ac/day (July to December)						
Land Use	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Forest	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07
Cropland	1.90E+07	5.30E+08	4.80E+08	9.90E+08	3.30E+08	8.40E+08
Pasture	1.20E+09	1.30E+09	1.30E+09	1.40E+09	1.30E+09	1.40E+09
Low Intensity Residential	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09
Commercial/Industrial /Transportation	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08
Other Urban	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08	5.59E+08
High Intensity Residential	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09	3.52E+09

Table D-3: Broad Run (VAN-A19R-01) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Septic**	**Direct Wildlife**
1	1.56E+12	2.97E+09	3.49E+11
2	2.19E+12	2.68E+09	3.16E+11
3	3.3E+12	2.97E+09	3.49E+11
4	3.19E+12	2.87E+09	3.38E+11
5	4.17E+12	2.97E+09	3.49E+11
6	4.04E+12	2.87E+09	3.38E+11
7	4.17E+12	2.97E+09	3.49E+11
8	3.3E+12	2.97E+09	3.49E+11
9	2.35E+12	2.87E+09	3.38E+11
10	2.43E+12	2.97E+09	3.49E+11
11	1.51E+12	2.87E+09	3.38E+11
12	1.56E+12	2.97E+09	3.49E+11

Table D-4: Broad Run (VAN-A19R-02) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	3.79E+11	4.25E+09	6.46E+11
2	5.33E+11	3.83E+09	5.83E+11
3	8.03E+11	4.25E+09	6.46E+11
4	7.76E+11	4.11E+09	6.25E+11
5	1.01E+12	4.25E+09	6.46E+11
6	9.79E+11	4.11E+09	6.25E+11
7	1.01E+12	4.25E+09	6.46E+11
8	8.03E+11	4.25E+09	6.46E+11
9	5.71E+11	4.11E+09	6.25E+11
10	5.91E+11	4.25E+09	6.46E+11
11	3.67E+11	4.11E+09	6.25E+11
12	3.79E+11	4.25E+09	6.46E+11

Table D-5: Bull Run Monthly Direct Deposition Rates (cfu/ac/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	5.93E+12	2.09E+10	5.43E+12
2	8.18E+12	1.89E+10	4.97E+12
3	1.22E+13	2.09E+10	5.5E+12
4	1.18E+13	2.02E+10	5.33E+12
5	1.53E+13	2.09E+10	5.5E+12
6	1.48E+13	2.02E+10	5.33E+12
7	1.53E+13	2.09E+10	5.5E+12
8	1.22E+13	2.09E+10	5.5E+12
9	8.75E+12	2.02E+10	5.33E+12
10	9.04E+12	2.09E+10	5.5E+12
11	5.74E+12	2.02E+10	5.33E+12
12	5.93E+12	2.09E+10	5.5E+12

Table D-6: Kettle Run Monthly Direct Deposition Rates (cfu/ac/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	3.07E+11	2.9E+09	1.03E+11
2	4.82E+11	2.61E+09	9.25E+10
3	7.6E+11	2.9E+09	1.03E+11
4	7.36E+11	2.8E+09	9.91E+10
5	9.89E+11	2.9E+09	1.03E+11
6	9.55E+11	2.8E+09	9.91E+10
7	9.89E+11	2.9E+09	1.03E+11
8	7.6E+11	2.9E+09	1.03E+11
9	5.17E+11	2.8E+09	9.91E+10
10	5.34E+11	2.9E+09	1.03E+11
11	2.96E+11	2.8E+09	9.91E+10
12	3.07E+11	2.9E+09	1.03E+11

Table D-7: Little Bull Run Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Septic**	**Direct Wildlife**
1	3.2E+11	7.59E+08	1.23E+11
2	4.34E+11	6.86E+08	1.11E+11
3	6.42E+11	7.59E+08	1.23E+11
4	6.21E+11	7.35E+08	1.19E+11
5	8.03E+11	7.59E+08	1.23E+11
6	7.76E+11	7.35E+08	1.19E+11
7	8.03E+11	7.59E+08	1.23E+11
8	6.42E+11	7.59E+08	1.23E+11
9	4.66E+11	7.35E+08	1.19E+11
10	4.81E+11	7.59E+08	1.23E+11
11	3.1E+11	7.35E+08	1.19E+11
12	3.2E+11	7.59E+08	1.23E+11

Table D-8: Occoquan River Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Septic**	**Direct Wildlife**
1	1.88E+10	2.36E+09	2.38E+11
2	2.77E+10	2.13E+09	2.15E+11
3	4.26E+10	2.36E+09	2.38E+11
4	4.12E+10	2.28E+09	2.31E+11
5	5.45E+10	2.36E+09	2.38E+11
6	5.28E+10	2.28E+09	2.31E+11
7	5.45E+10	2.36E+09	2.38E+11
8	4.26E+10	2.36E+09	2.38E+11
9	2.98E+10	2.28E+09	2.31E+11
10	3.07E+10	2.36E+09	2.38E+11
11	1.82E+10	2.28E+09	2.31E+11
12	1.88E+10	2.36E+09	2.38E+11

Table D-9: Popes Head Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Septic**	**Direct Wildlife**
1	1.37E+10	1.33E+09	2.12E+11
2	1.93E+10	1.21E+09	1.92E+11
3	2.9E+10	1.33E+09	2.12E+11
4	2.81E+10	1.29E+09	2.06E+11
5	3.69E+10	1.33E+09	2.12E+11
6	3.57E+10	1.29E+09	2.06E+11
7	3.69E+10	1.33E+09	2.12E+11
8	2.9E+10	1.33E+09	2.12E+11
9	2.07E+10	1.29E+09	2.06E+11
10	2.13E+10	1.33E+09	2.12E+11
11	1.32E+10	1.29E+09	2.06E+11
12	1.37E+10	1.33E+09	2.12E+11

Table D-10: South Run Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Septic**	**Direct Wildlife**
1	4.72E+10	1.62E+09	4.91E+10
2	6.4E+10	1.47E+09	4.44E+10
3	9.44E+10	1.62E+09	4.91E+10
4	9.14E+10	1.57E+09	4.76E+10
5	1.18E+11	1.62E+09	4.91E+10
6	1.14E+11	1.57E+09	4.76E+10
7	1.18E+11	1.62E+09	4.91E+10
8	9.44E+10	1.62E+09	4.91E+10
9	6.85E+10	1.57E+09	4.76E+10
10	7.08E+10	1.62E+09	4.91E+10
11	4.57E+10	1.57E+09	4.76E+10
12	4.72E+10	1.62E+09	4.91E+10

Appendix E

Water Quality Calibration and Validation Plots

E.1 Broad Run (Segment VAN-A19R-01)

Figure E-1: Fecal Coliform Calibration Broad Run (Segment VAN-A19R-01)

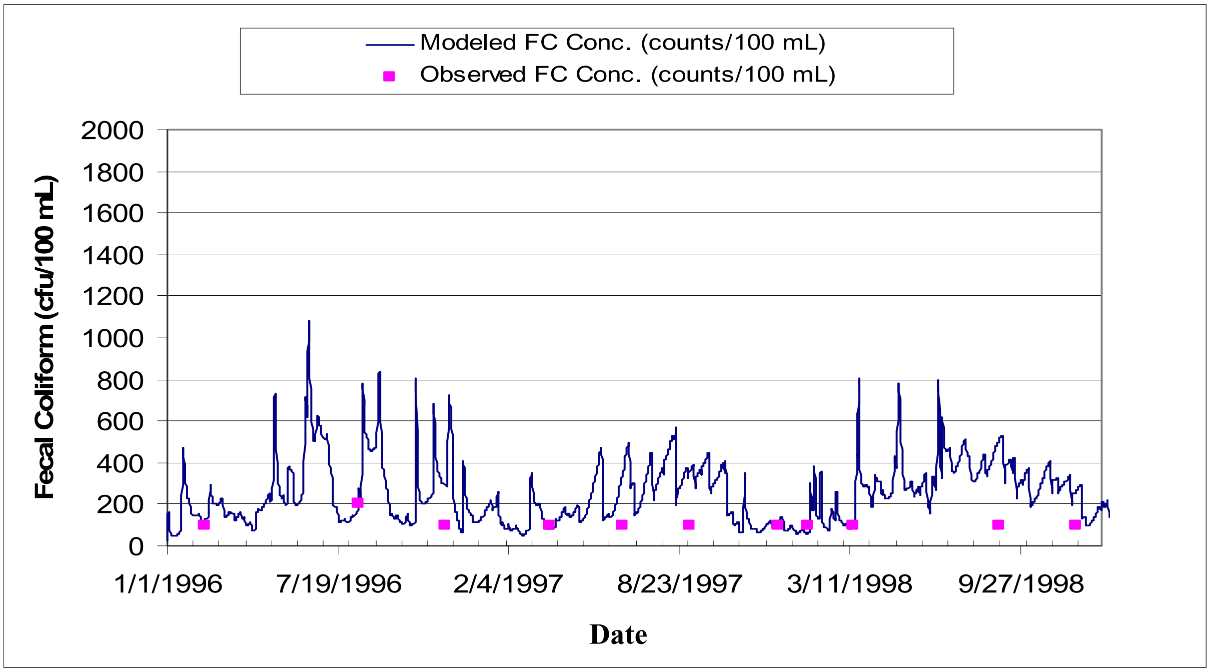
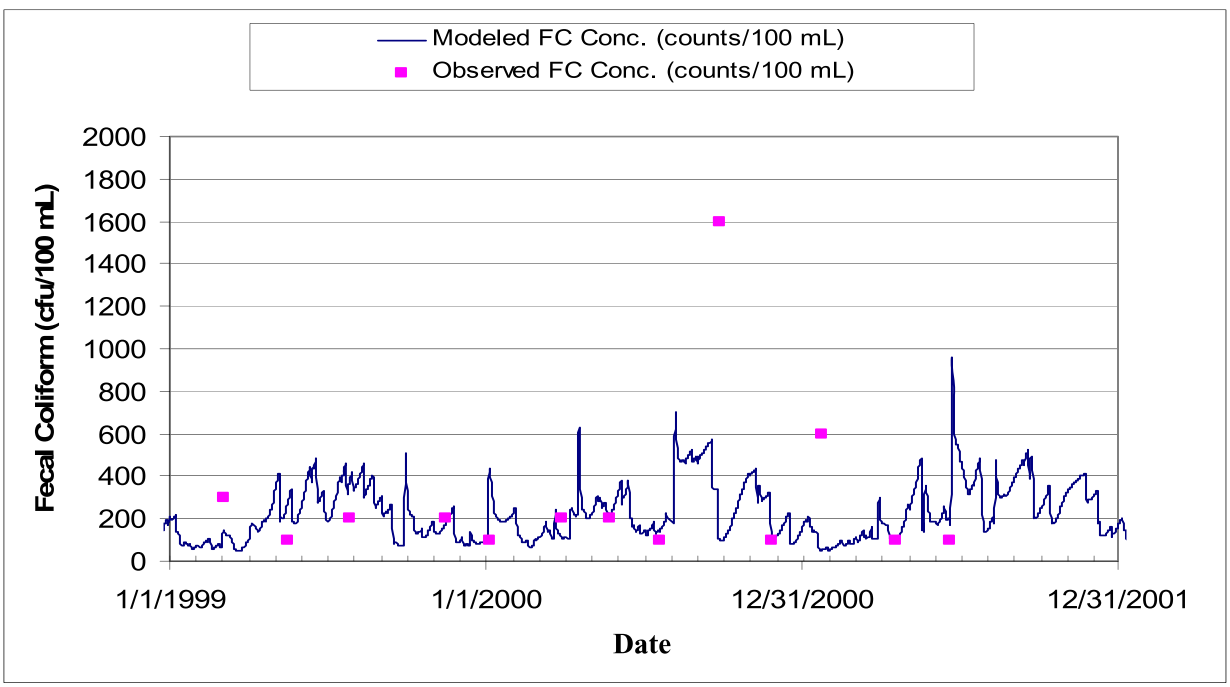


Figure E-2: Fecal Coliform Validation Broad Run (Segment VAN-A19R-01)



E.2 Broad Run (Segment VAN-A19R-02)

Figure E-3: Fecal Coliform Calibration Broad Run (Segment VAN-A19R-02)

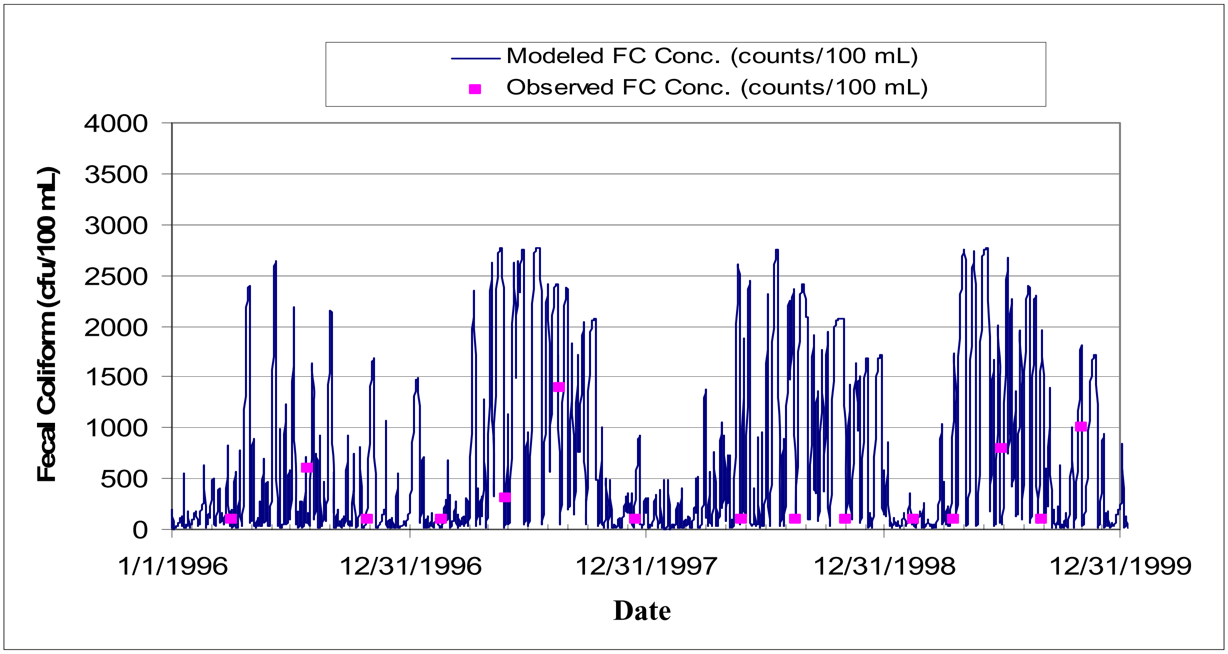
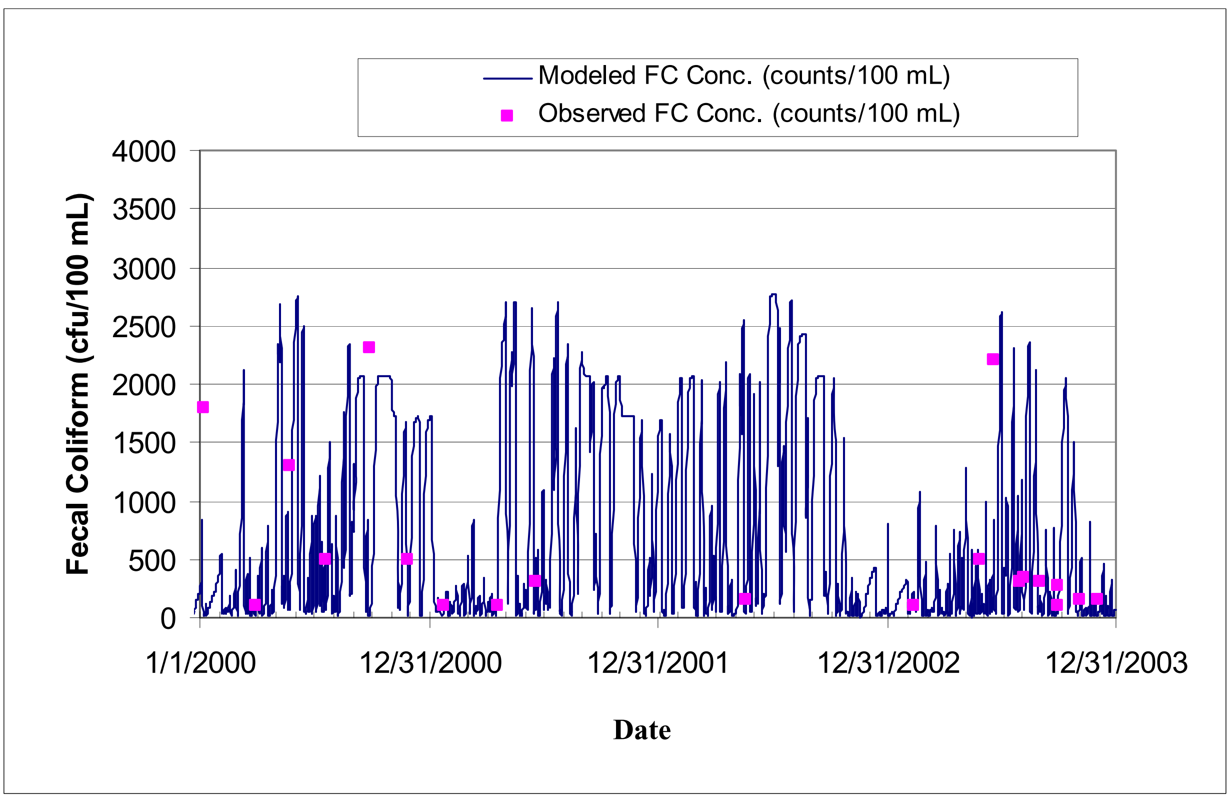


Figure E-4: Fecal Coliform Validation Broad Run (Segment VAN-A19R-02)



E.3 Bull Run (Segment VAN-A23R-01)

Figure E-5: Fecal Coliform Calibration Bull Run (Segment VAN-A23R-01)

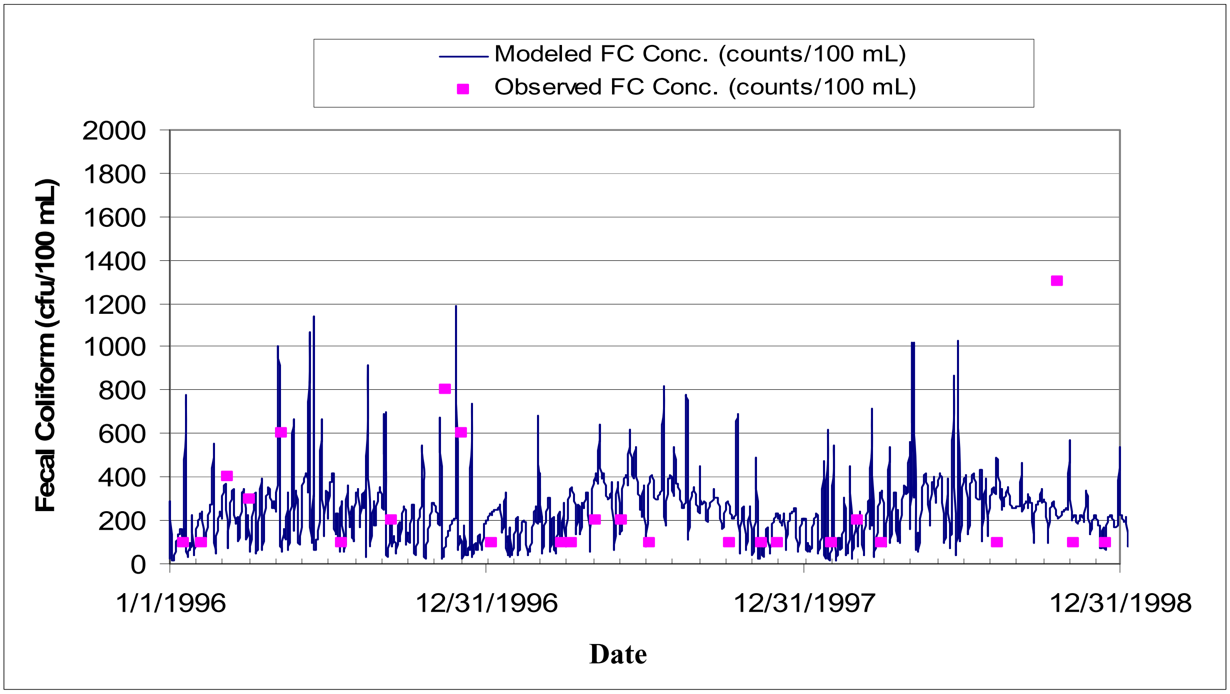
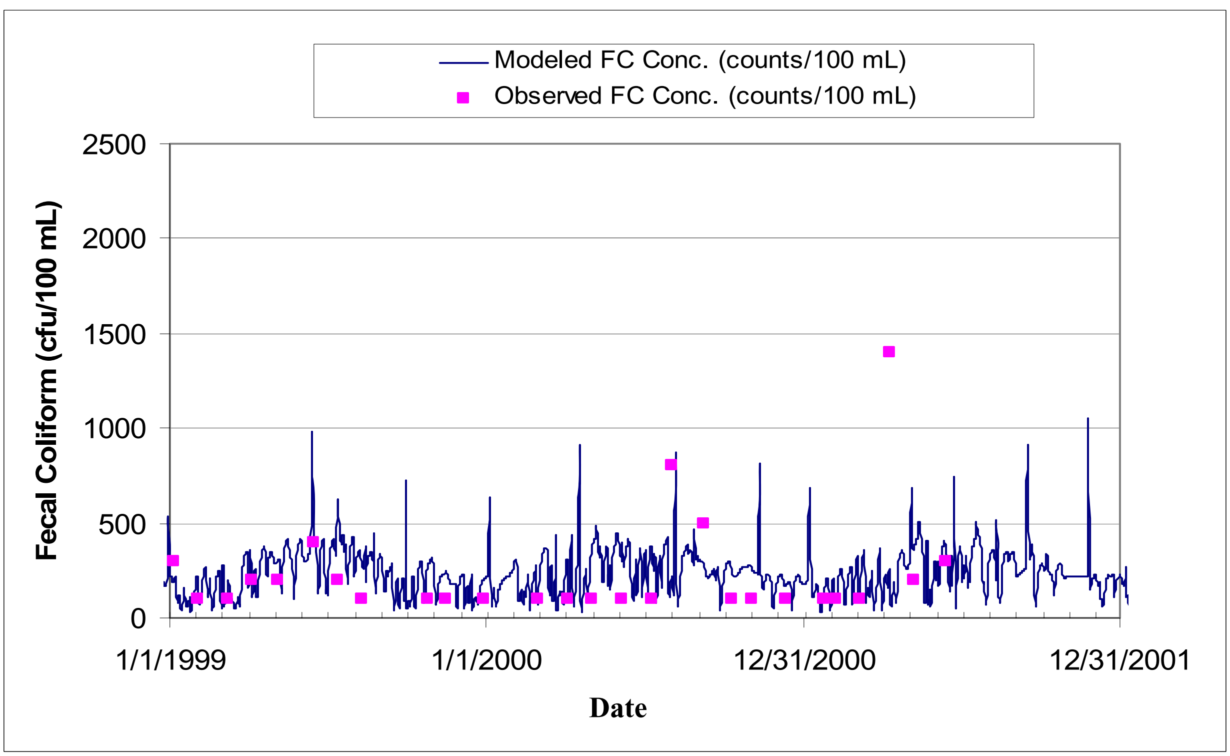


Figure E-6: Fecal Coliform Validation Bull Run (Segment VAN-A23R-01)



E.4 Kettle Run (Segment VAN-A19R-03)

Figure E-7: Fecal Coliform Calibration Kettle Run (Segment VAN-A19R-03)

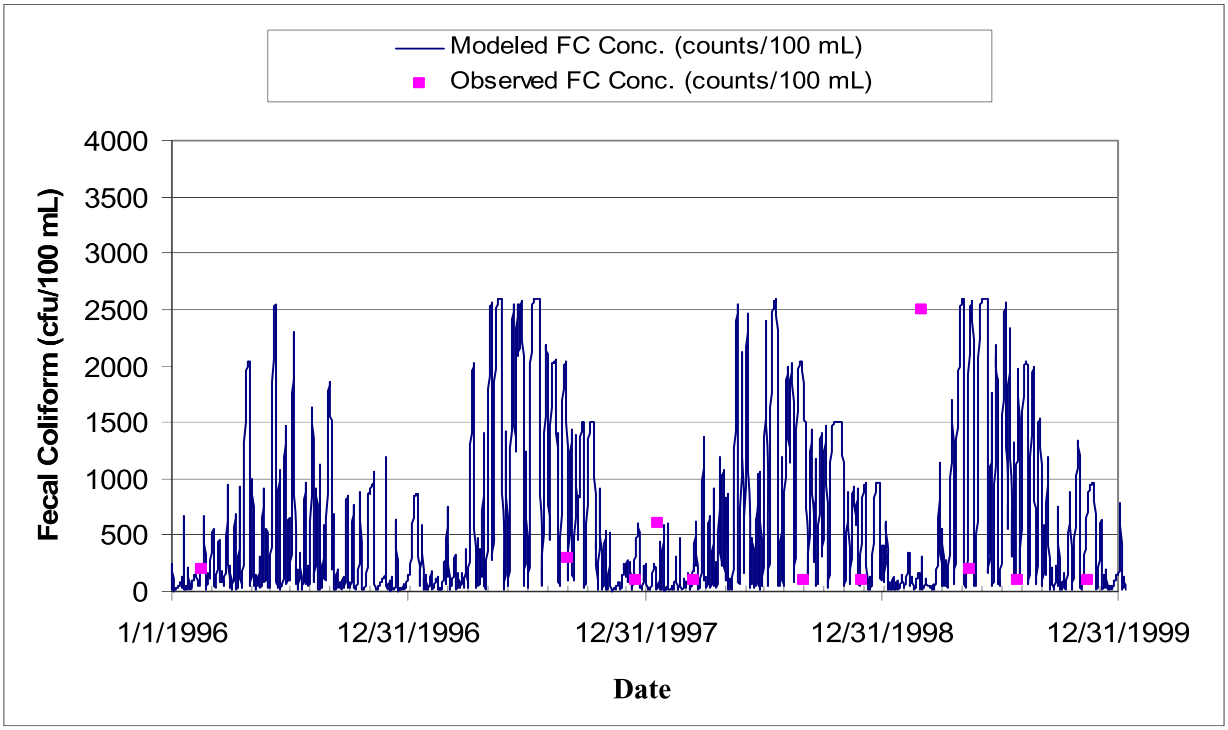
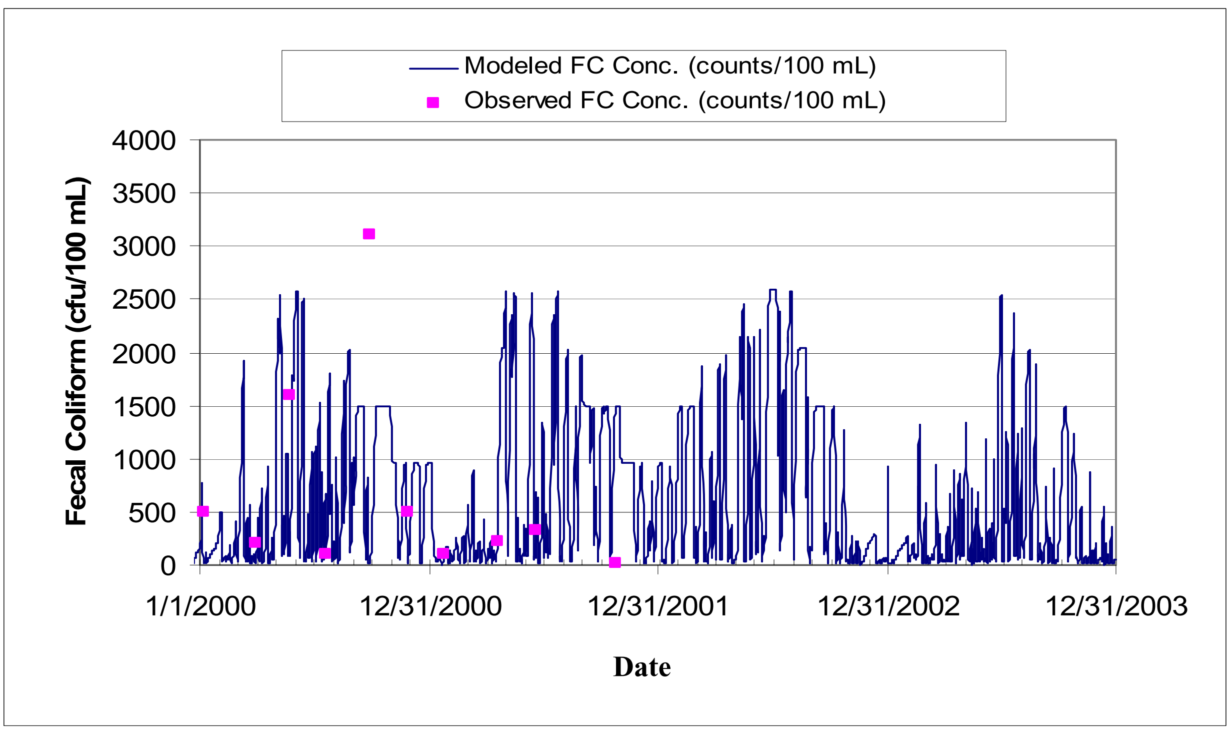


Figure E-8: Fecal Coliform Validation Kettle Run (Segment VAN-A19R-03)



E.5 Little Bull Run (Segment VAN-A21R-01)

Figure E-9: Fecal Coliform Calibration Little Bull Run (Segment VAN-A21R-01)

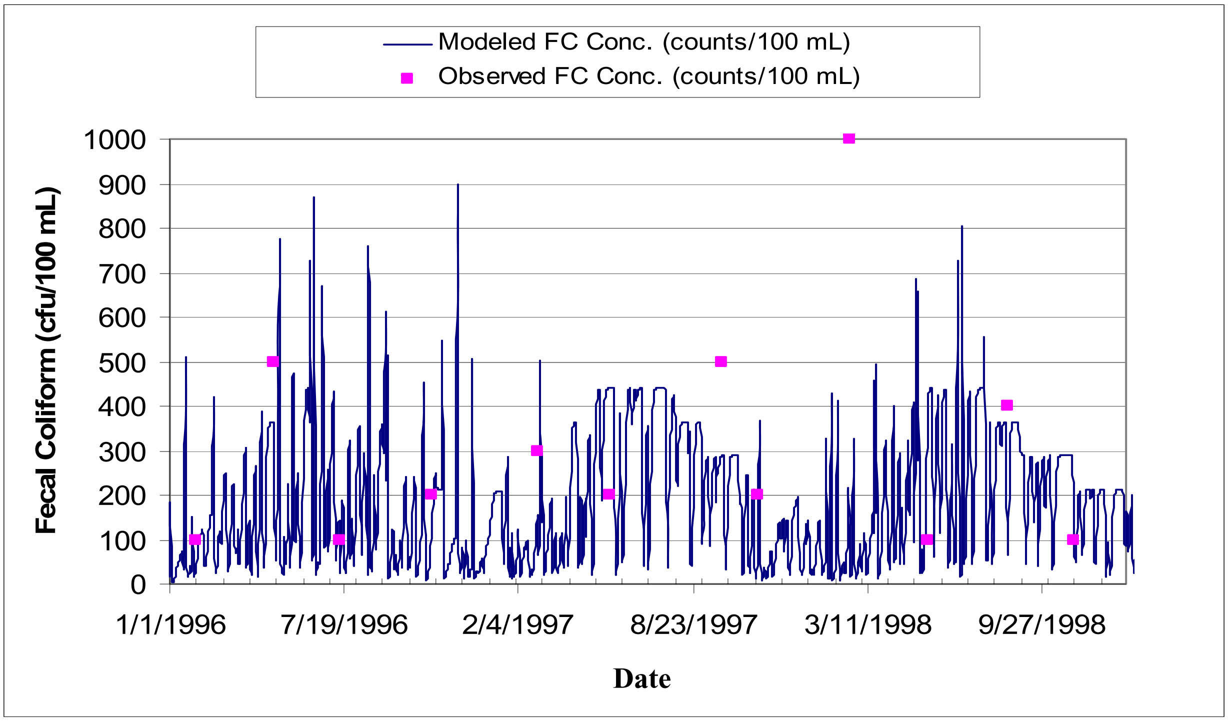
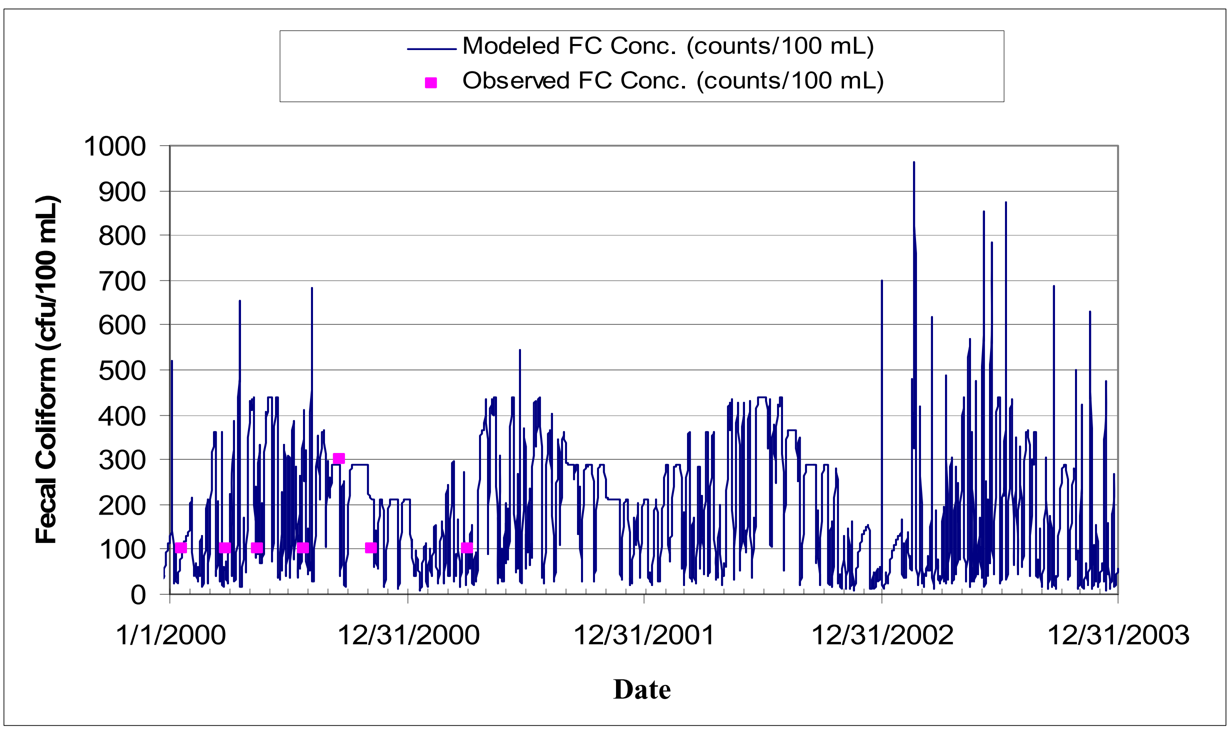


Figure E-10: Fecal Coliform Validation Little Bull Run (Segment VAN-A21R-01)



E.6 Occoquan River (Segment VAN-A20R-01)

Figure E-11: Fecal Coliform Calibration Occoquan River (Segment VAN-A20R-01)

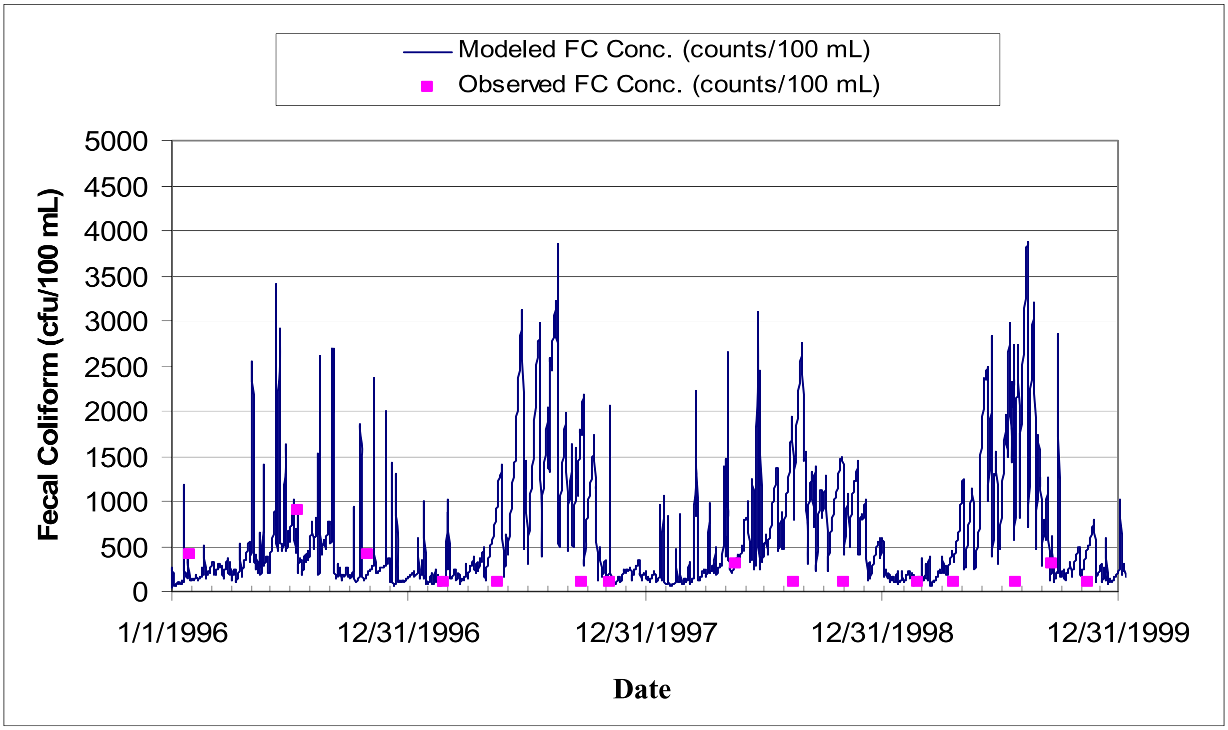
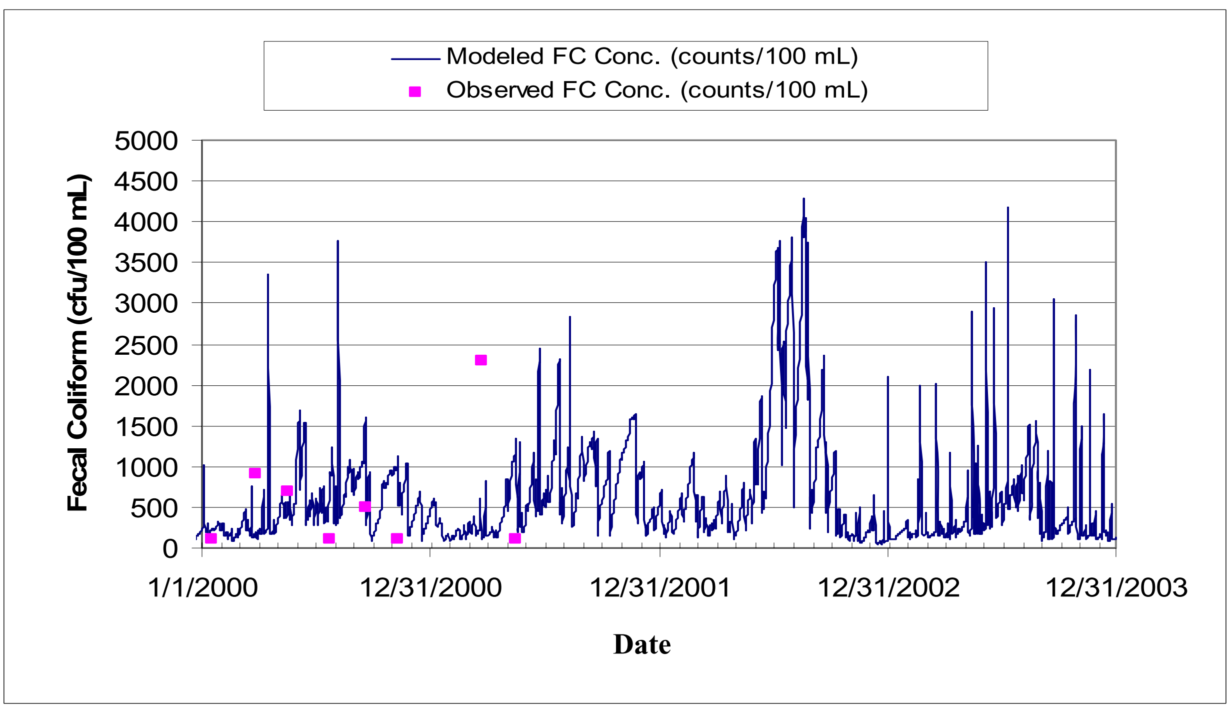


Figure E-12: Fecal Coliform Validation Occoquan River (Segment VAN-A20R-01)



E.7 Popes Head Creek (Segment VAN-A23R-02)

Figure E-13: Fecal Coliform Calibration Popes Head Creek (Segment VAN-A23R-02)

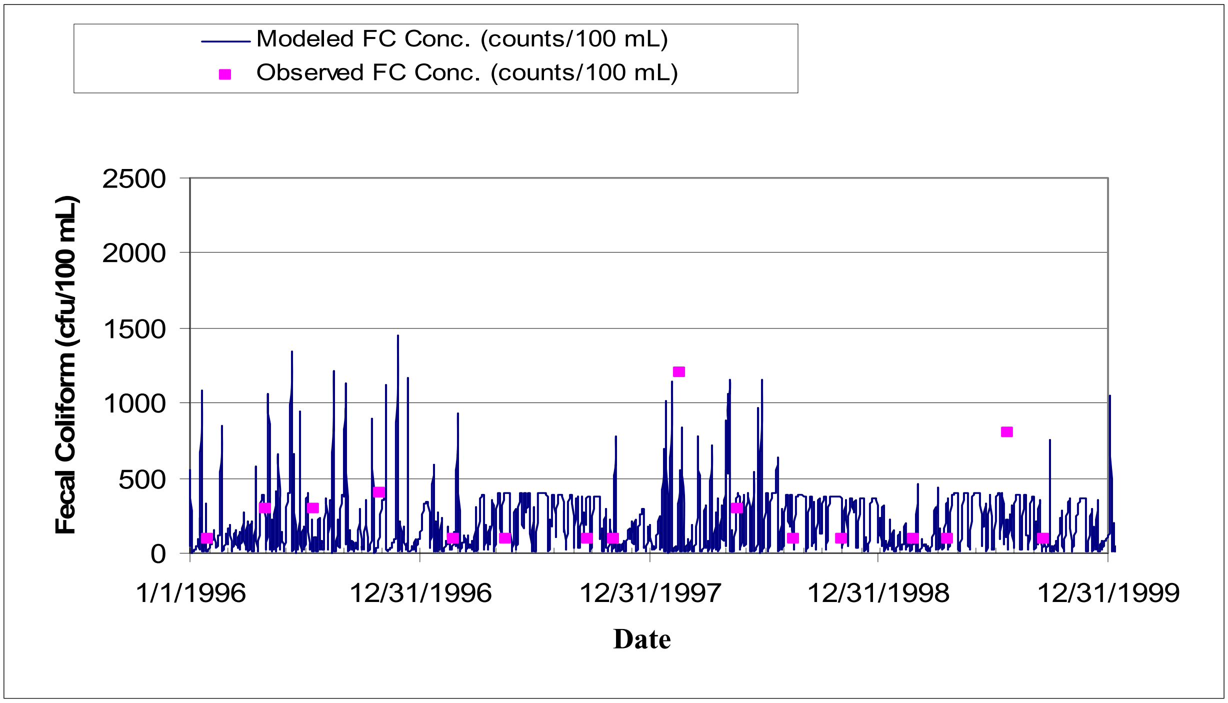
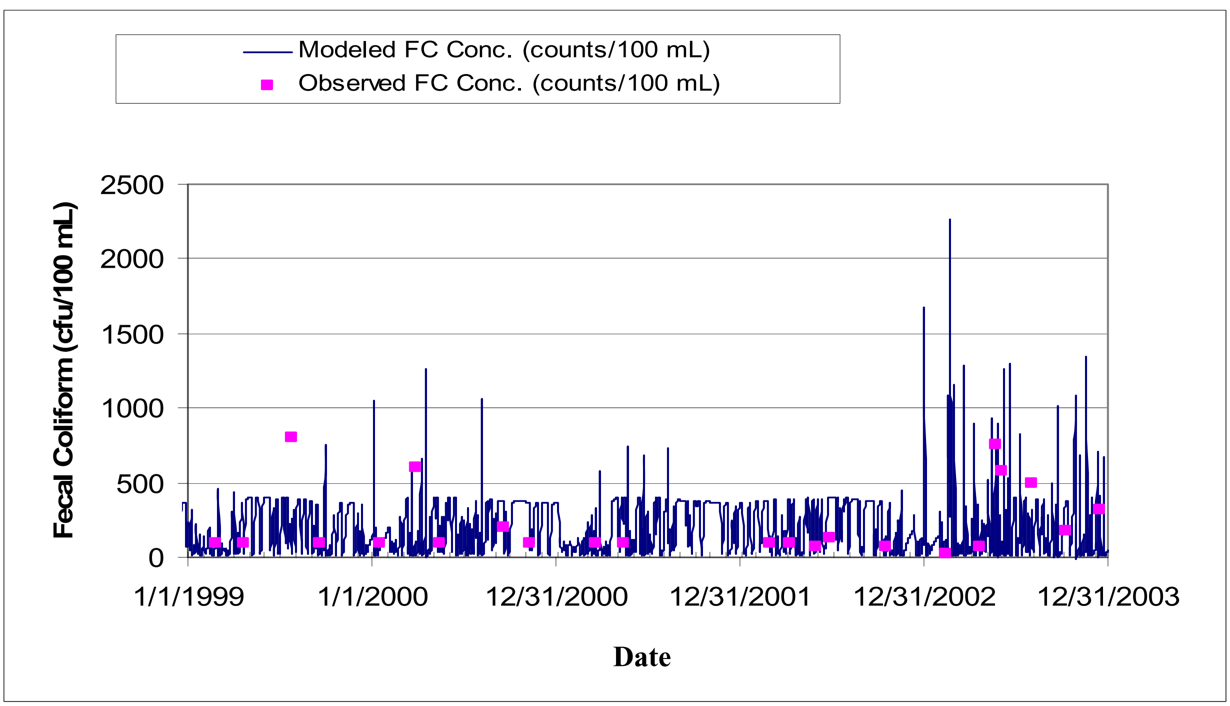


Figure E-14: Fecal Coliform Validation Popes Head Creek (Segment VAN-A23R-02)



E.8 South Run (Segment VAN-A19R-04)

Figure E-15: Fecal Coliform Calibration South Run (Segment VAN-A19R-04)

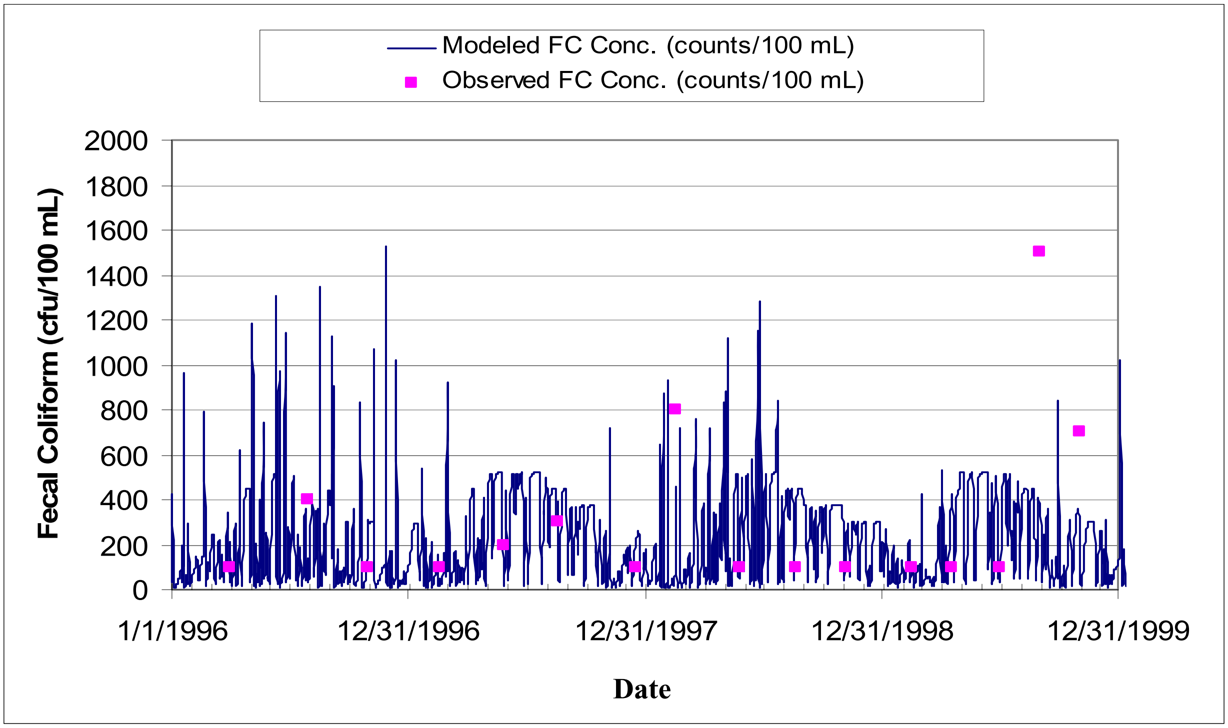
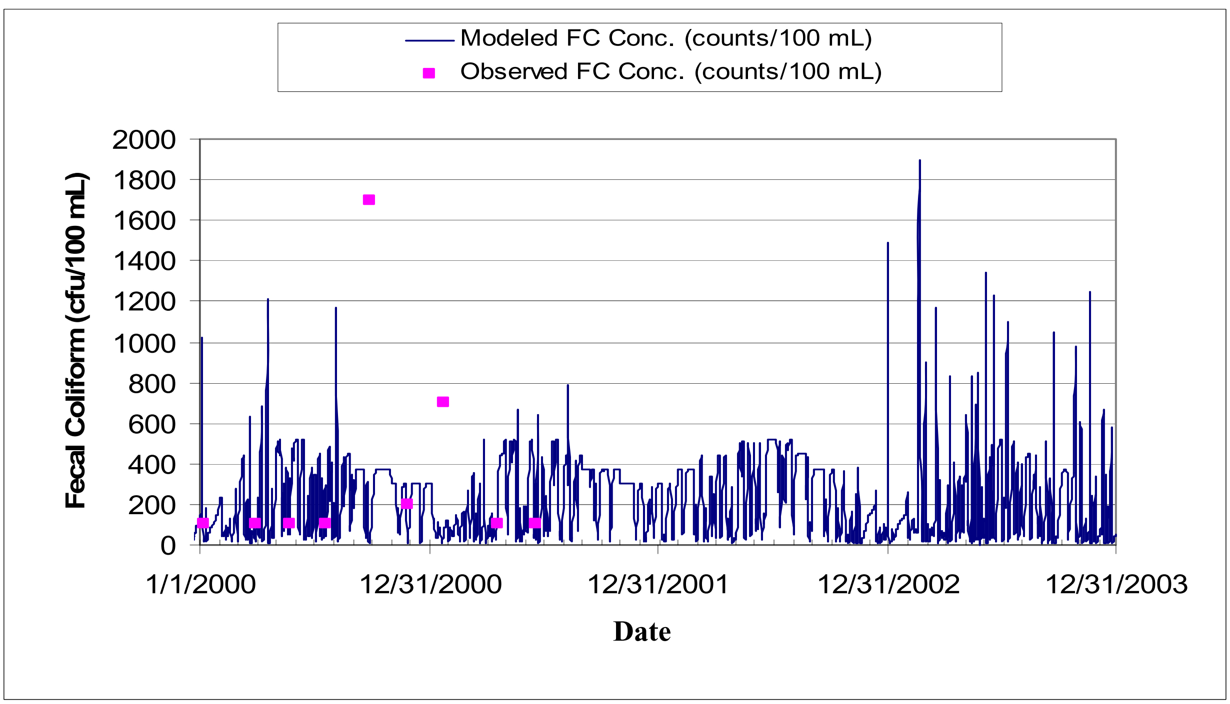


Figure E-16: Fecal Coliform Validation South Run (Segment VAN-A19R-04)



Appendix F

Fecal Coliform and *E. coli* Geometric Mean and Instantaneous Concentrations under Existing Conditions

F.1 Broad Run (Segment VAN-A19R-01)

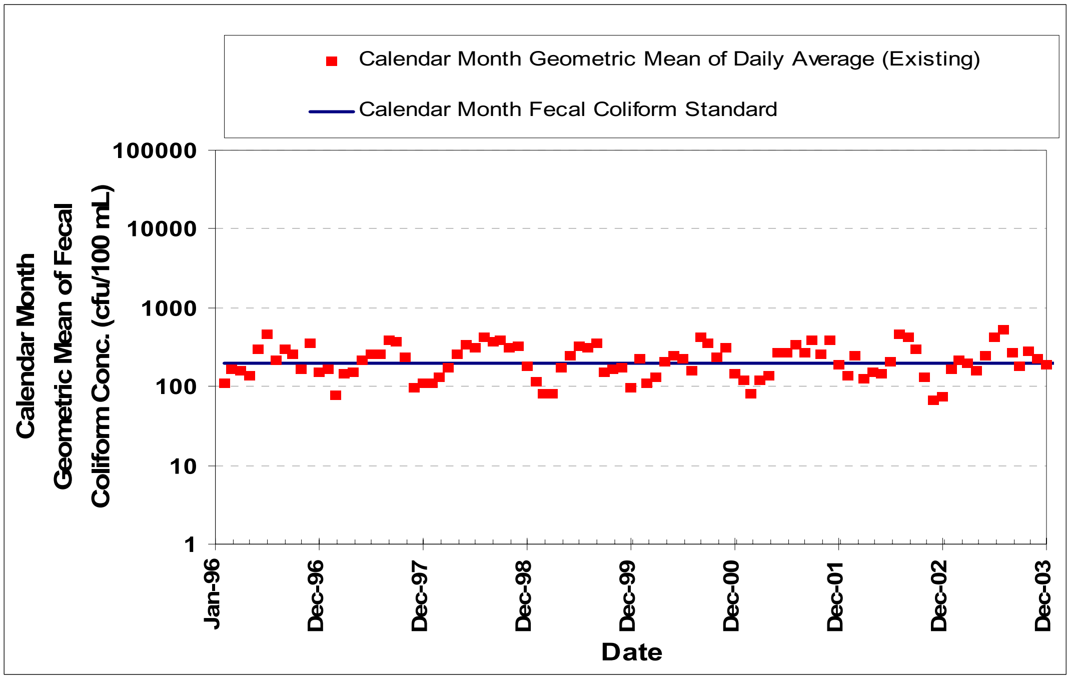


Figure F-1: Broad Run (Segment VAN-A19R-01) Fecal Coliform Geometric Mean Existing Conditions

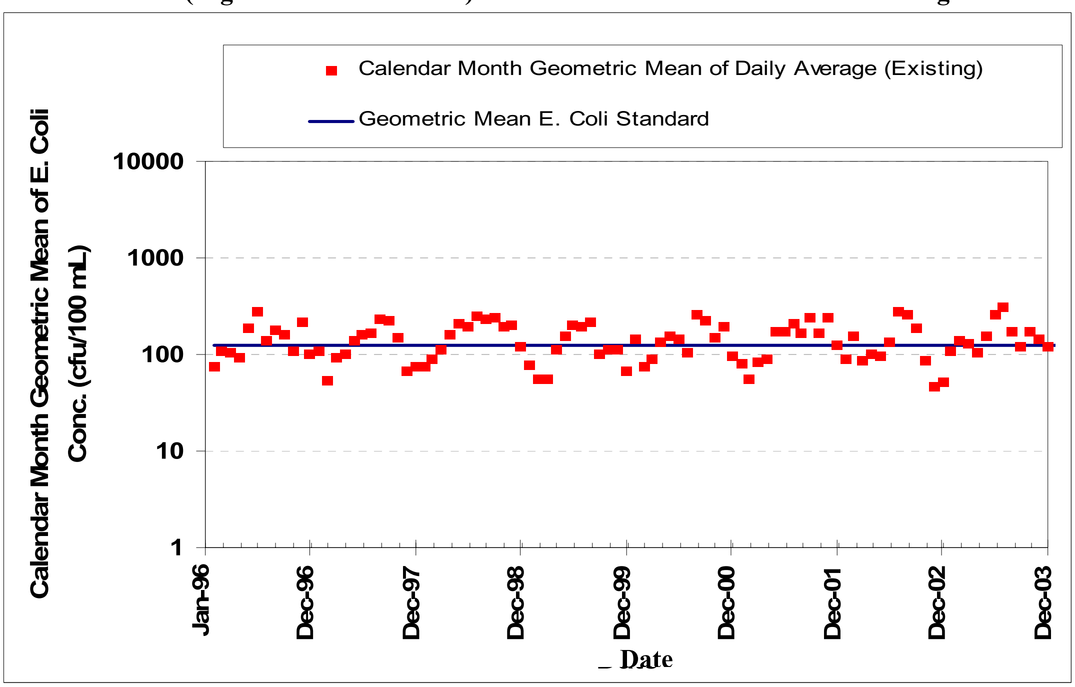


Figure F-2: Broad Run (Segment VAN-A19R-01) E. coli Geometric Mean Existing Conditions

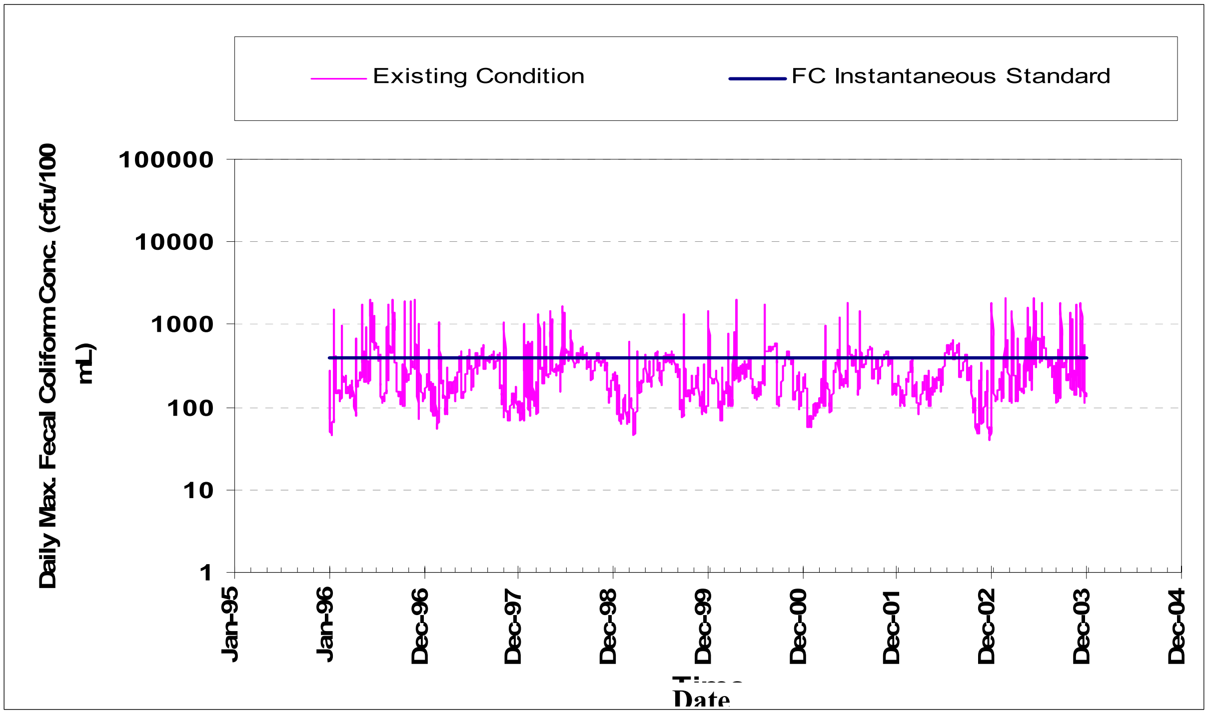


Figure F-3: Broad Run (Segment VAN-A19R-01) Fecal Coliform Instantaneous Existing Conditions

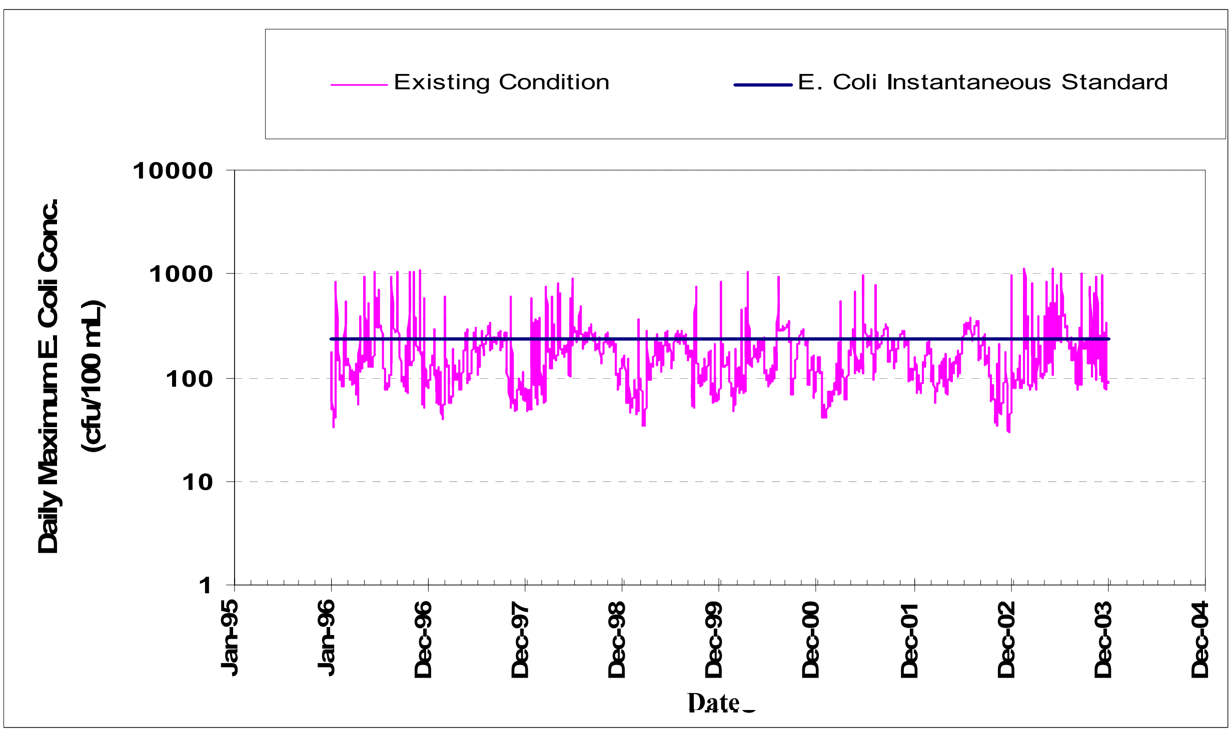


Figure F-4: Broad Run (Segment VAN-A19R-01) E. coli Instantaneous Existing Conditions

F.2 Broad Run (Segment VAN-A19R-02)

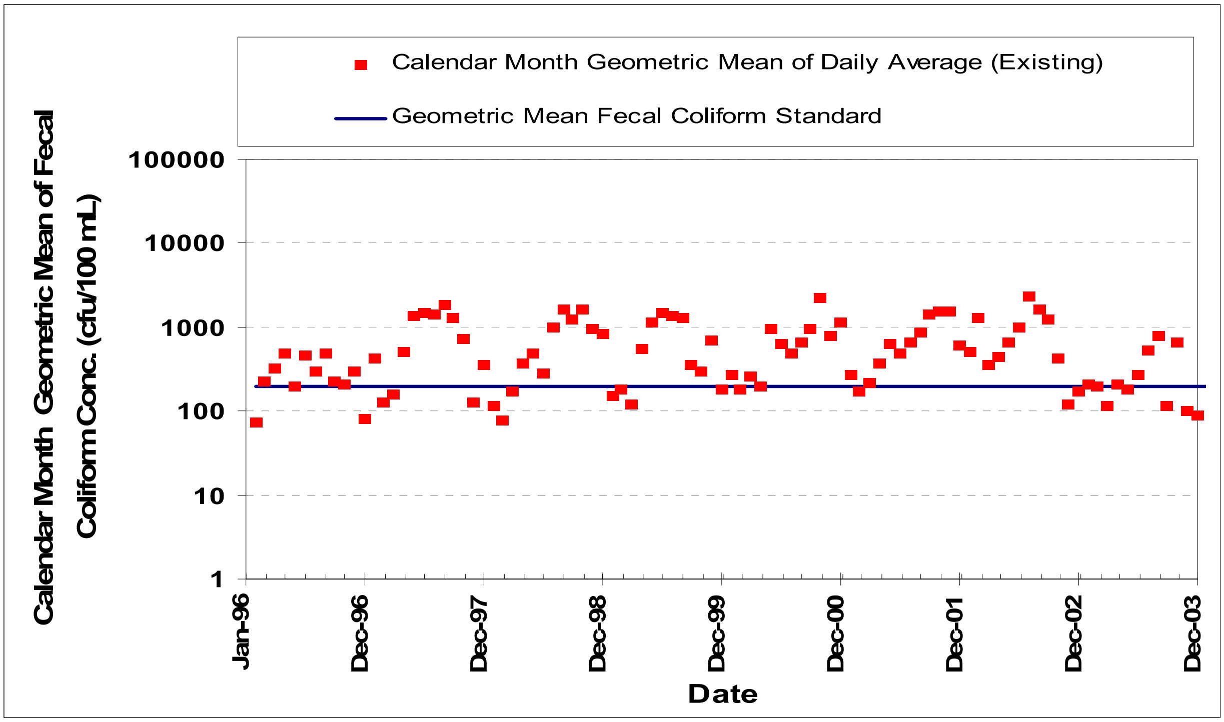


Figure F-5: Broad Run (Segment VAN-A19R-02) Fecal Coliform Geometric Mean Existing Conditions

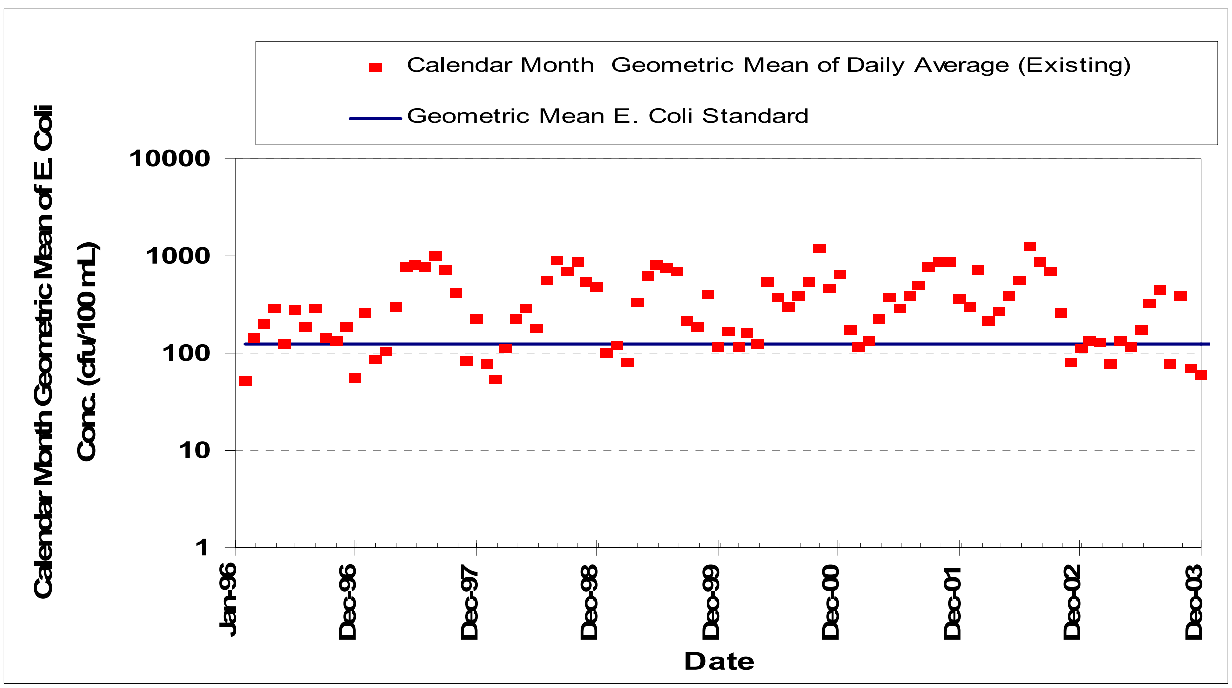


Figure F-6: Broad Run (Segment VAN-A19R-02) E. coli Geometric Mean Existing Conditions

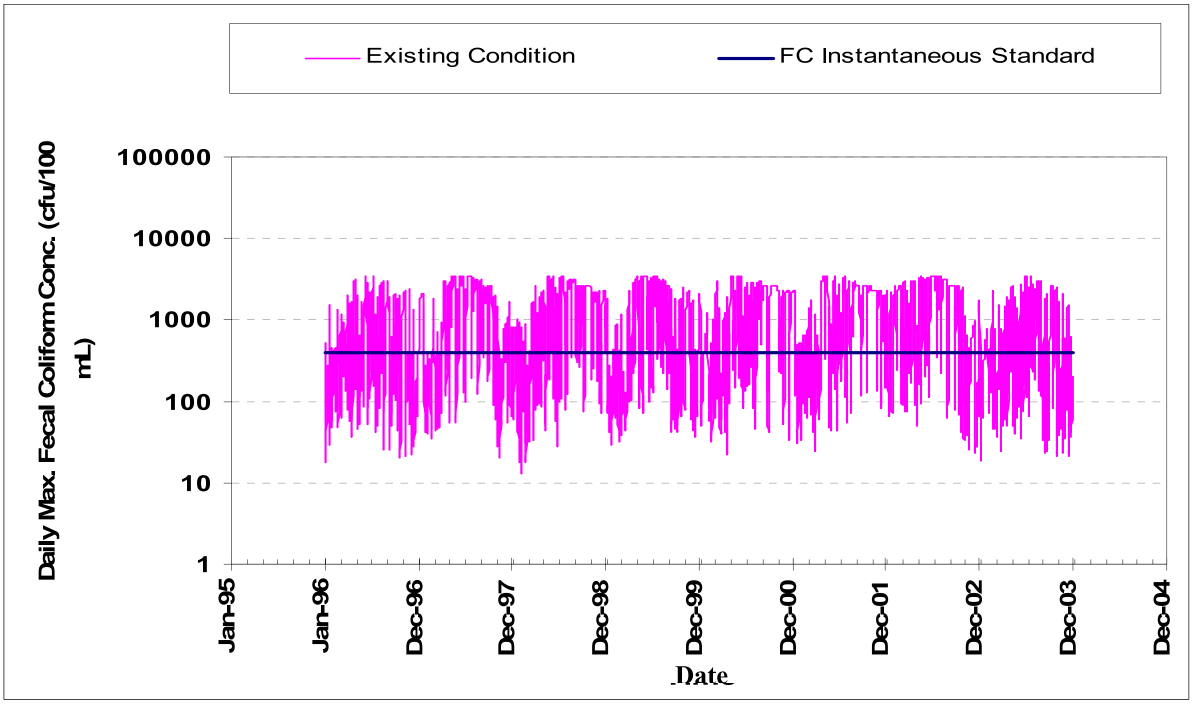


Figure F-7: Broad Run (Segment VAN-A19R-02) Fecal Coliform Instantaneous Existing Conditions

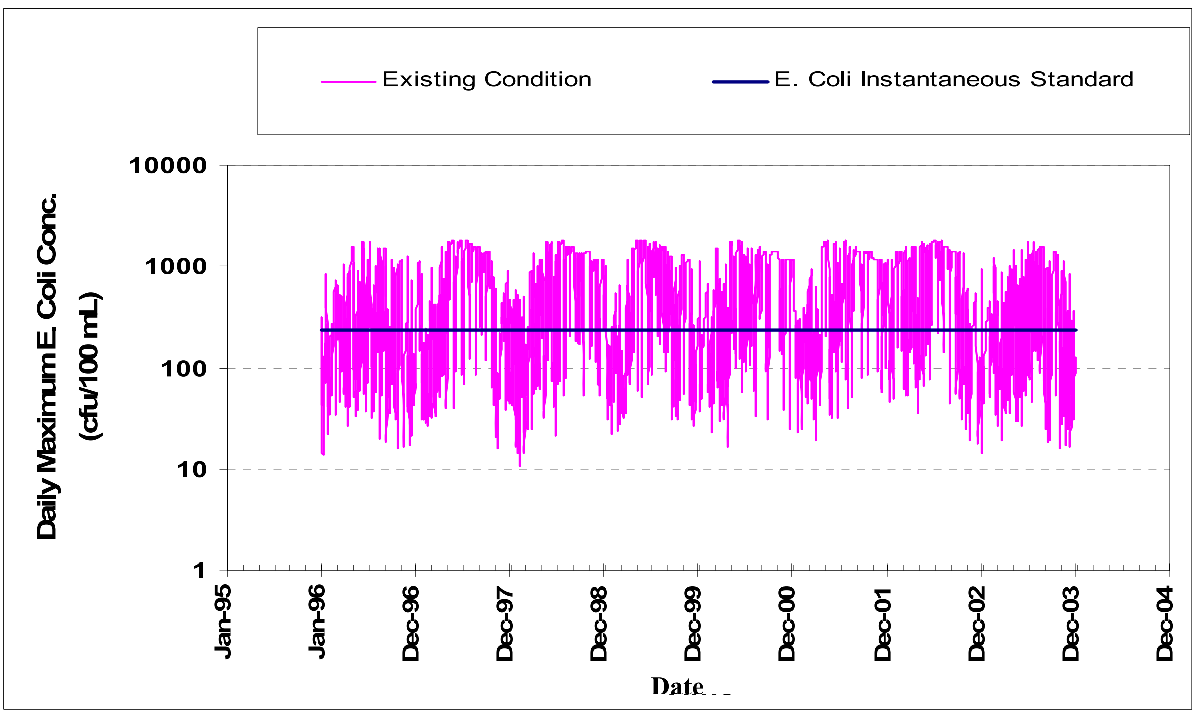


Figure F-8: Broad Run (Segment VAN-A19R-02) E. coli Instantaneous Existing Conditions

F.3 Broad Run (Segment VAN-A19R-05)

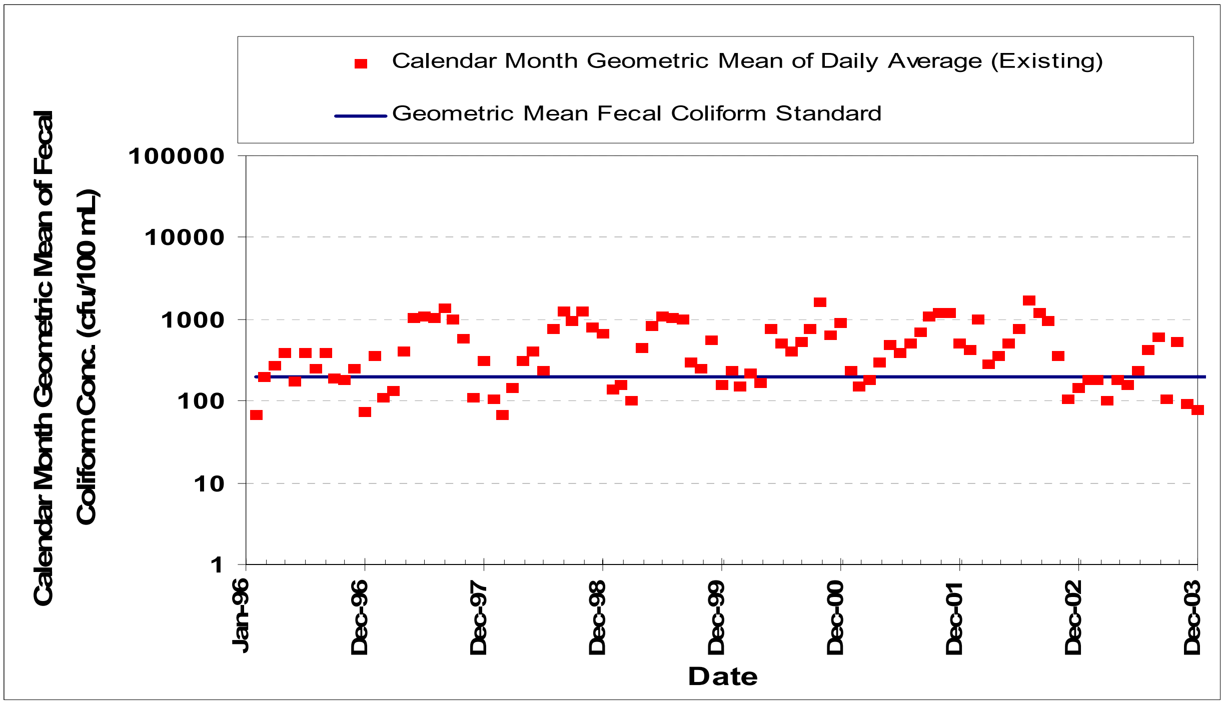


Figure F-9: Broad Run (Segment VAN-A19R-05) Fecal Coliform Geometric Mean Existing Conditions

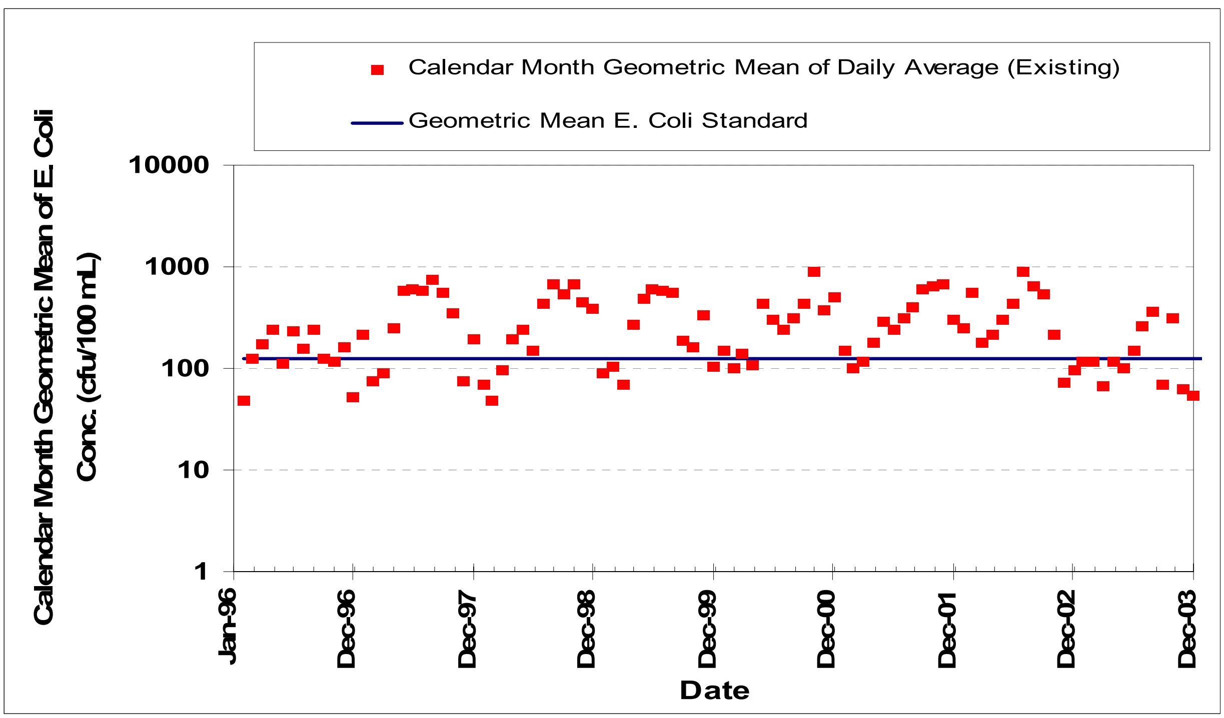


Figure F-10: Broad Run (Segment VAN-A19R-05) E. coli Geometric Mean Existing Conditions

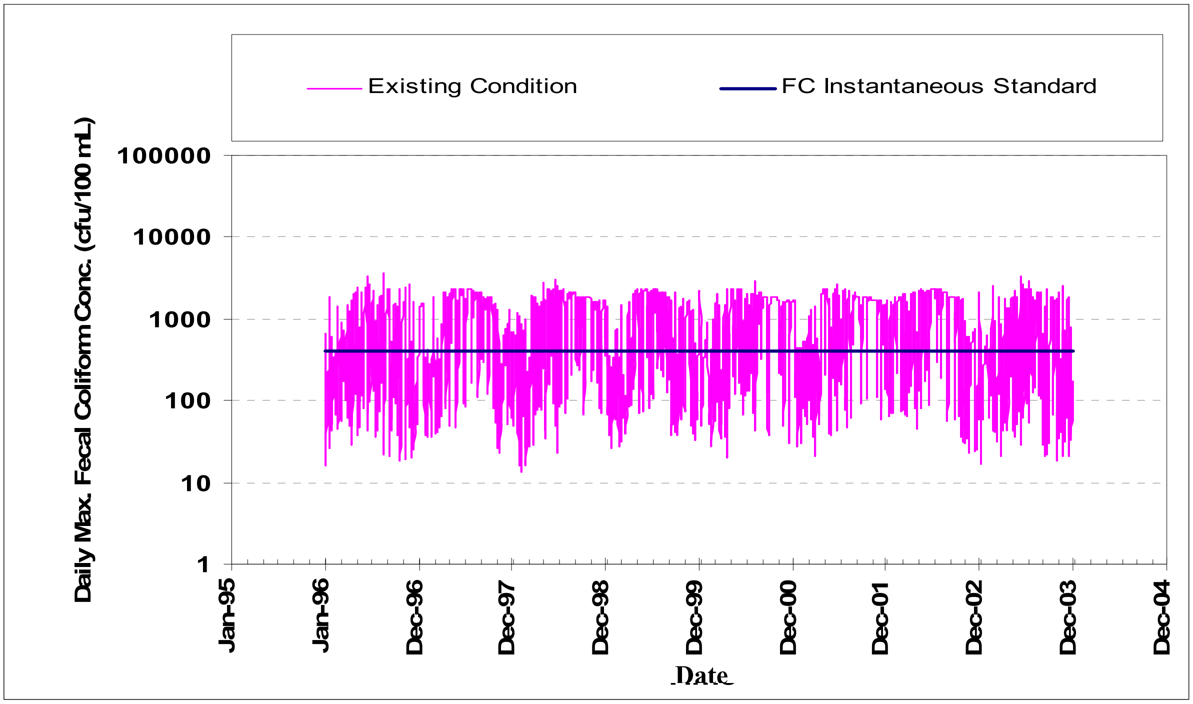


Figure F-11: Broad Run (Segment VAN-A19R-05) Fecal Coliform Instantaneous Existing Conditions

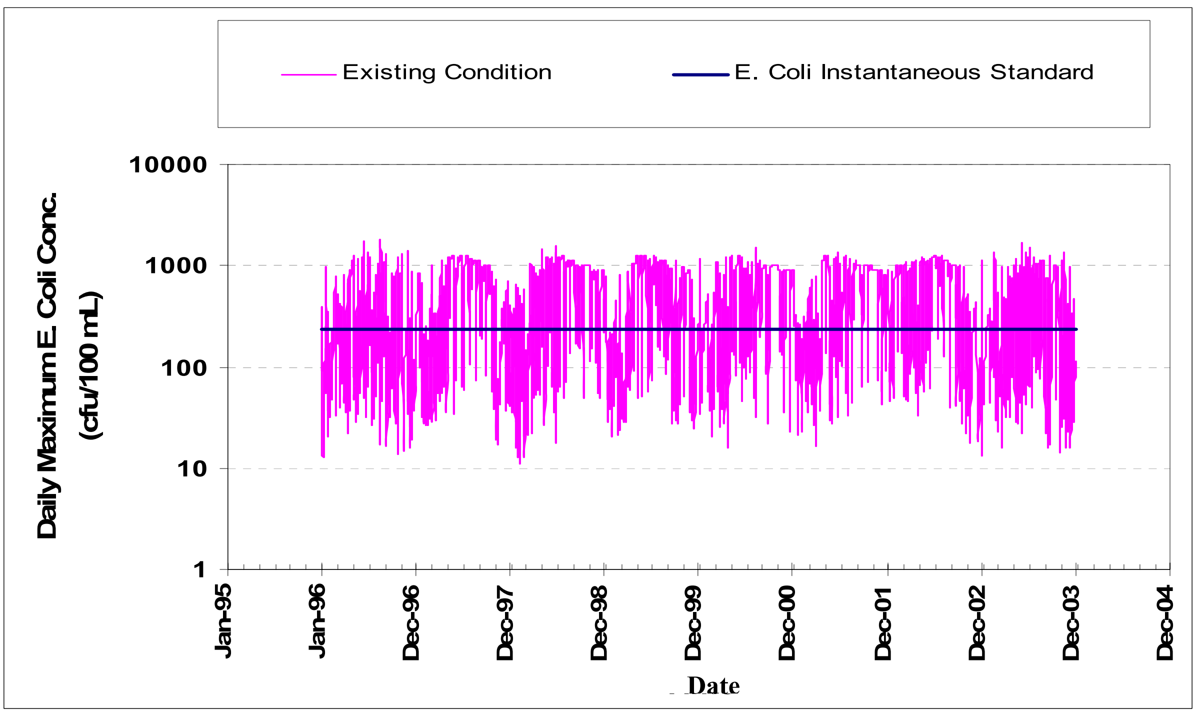


Figure F-12: Broad Run (Segment VAN-A19R-05) E. coli Instantaneous Existing Conditions

F.5 Kettle Run (Segment VAN-A19R-03)

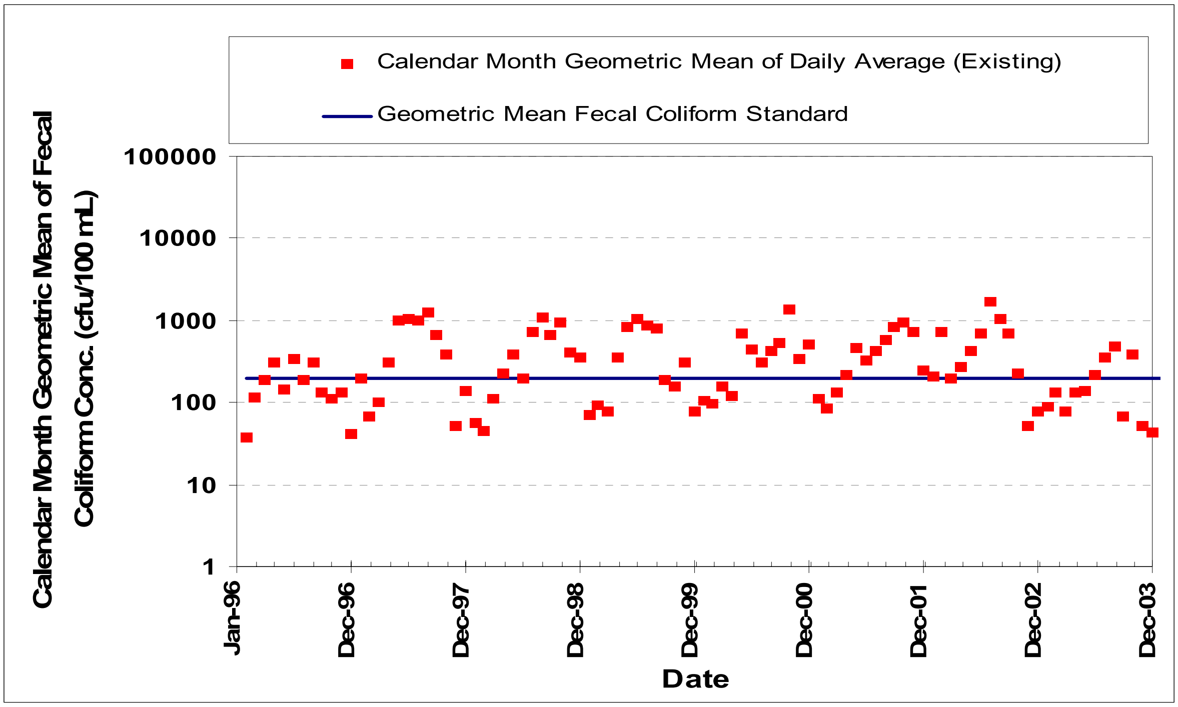


Figure F-17: Kettle Run (Segment VAN-A19R-03) Fecal Coliform Geometric Mean Existing Conditions

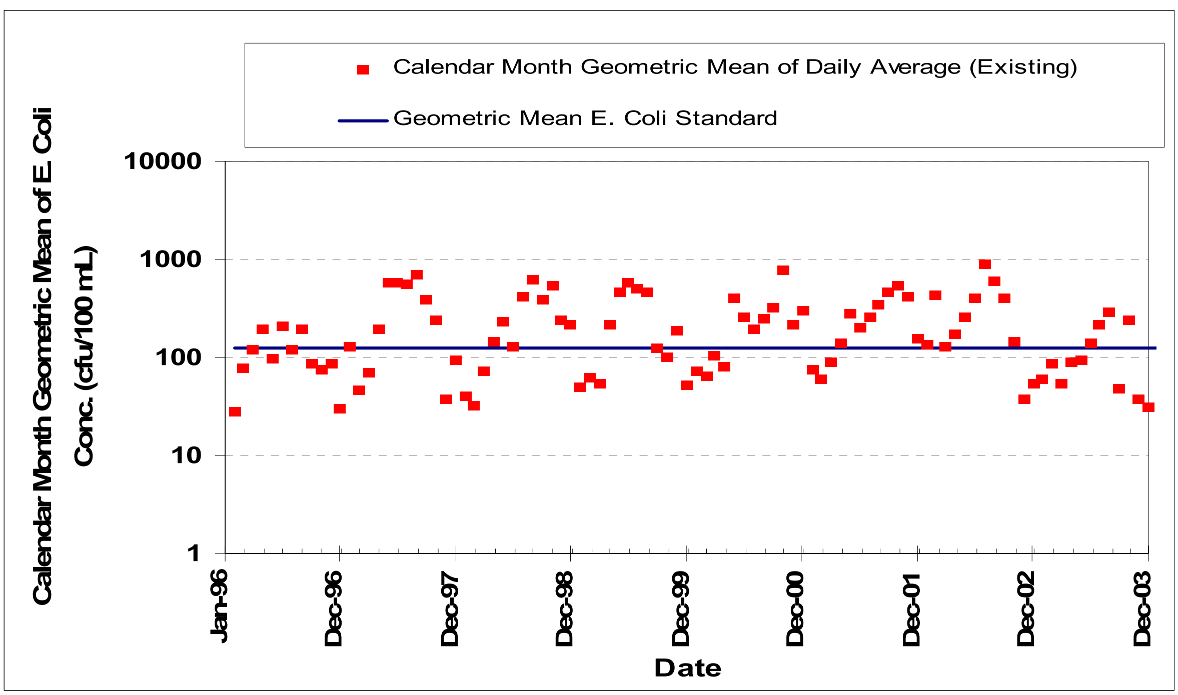


Figure F-18: Kettle Run (Segment VAN-A19R-03) E. coli Geometric Mean Existing Conditions

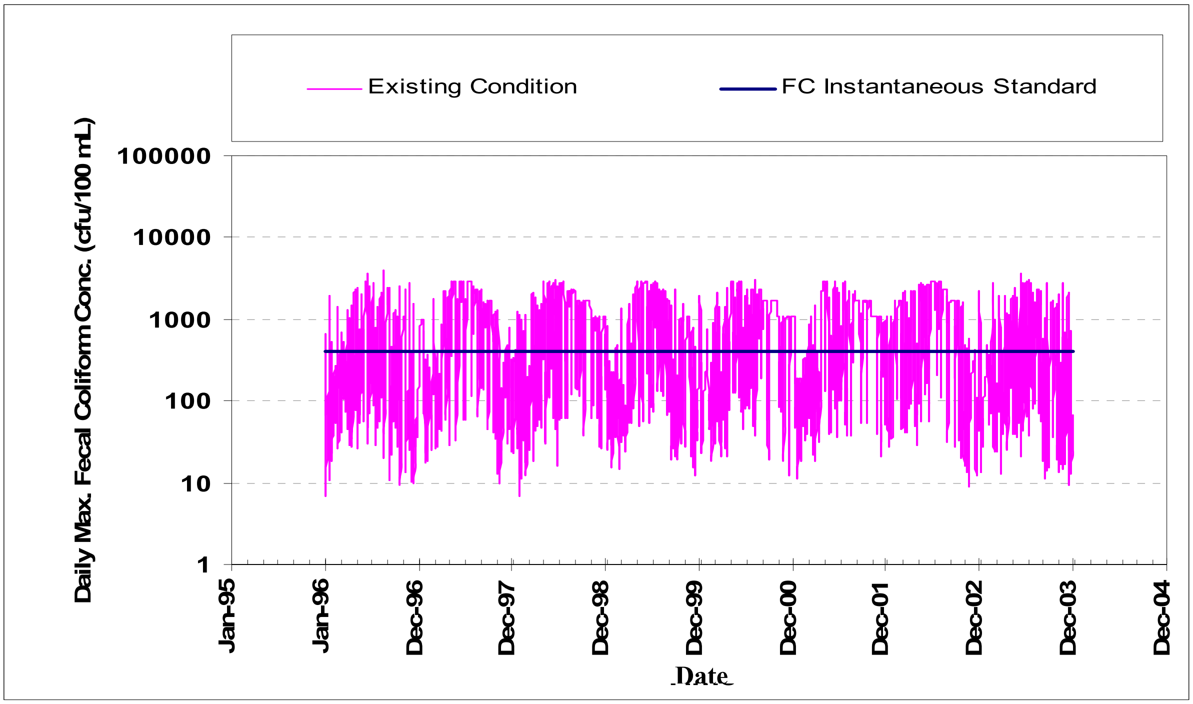


Figure F-19: Kettle Run (Segment VAN-A19R-03) Fecal Coliform Instantaneous Existing Conditions

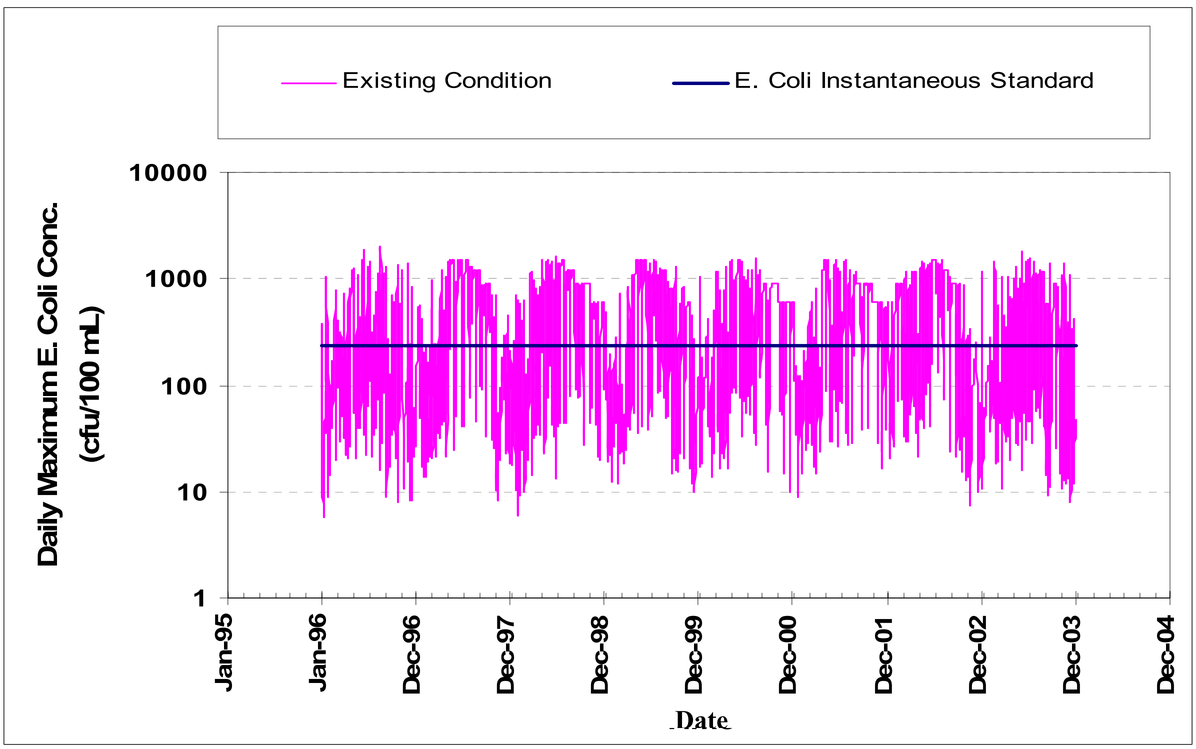


Figure F-20: Kettle Run (Segment VAN-A19R-03) E. coli Instantaneous Existing Conditions

F.9 South Run (Segment VAN-A19R-04)

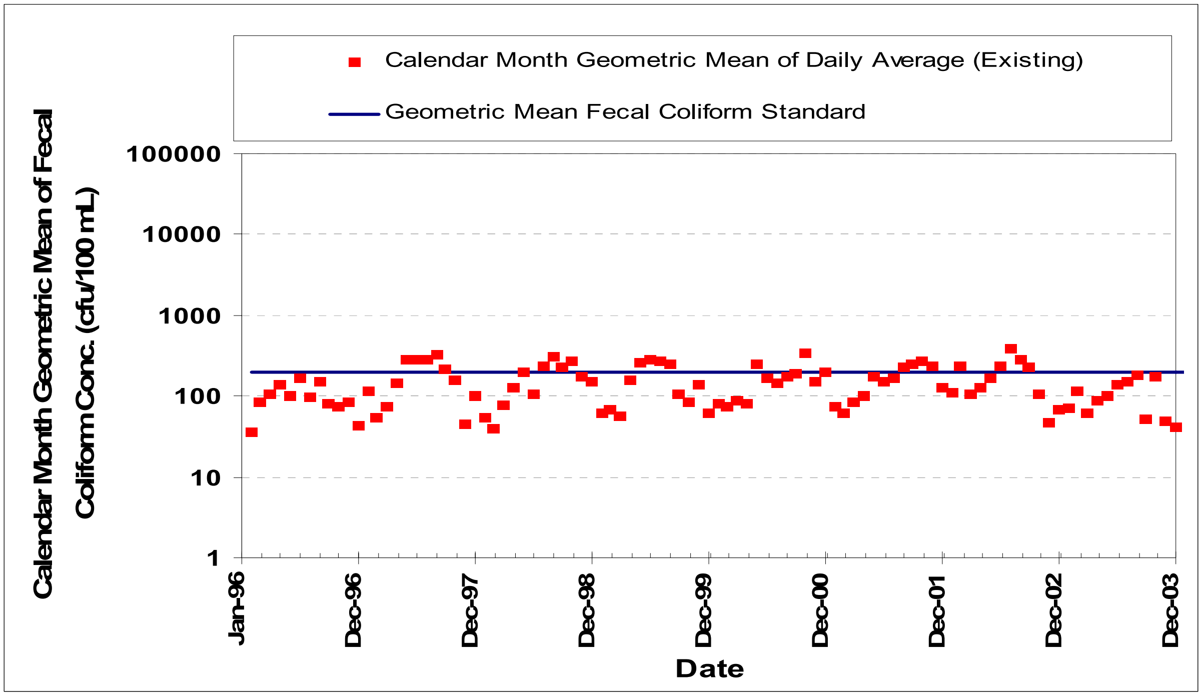


Figure F-33: South Run (Segment VAN-A19R-04) Fecal Coliform Geometric Mean Existing Conditions

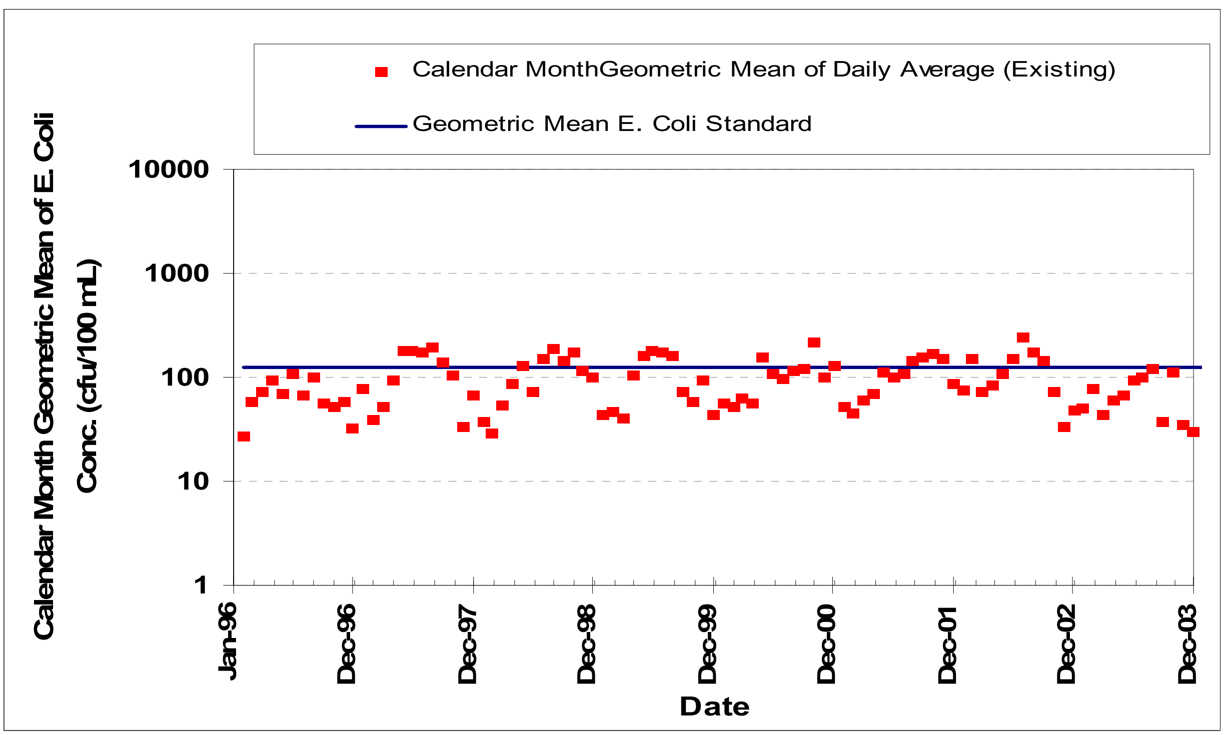


Figure F-34: South Run (Segment VAN-A19R-04) E. coli Geometric Mean Existing Conditions

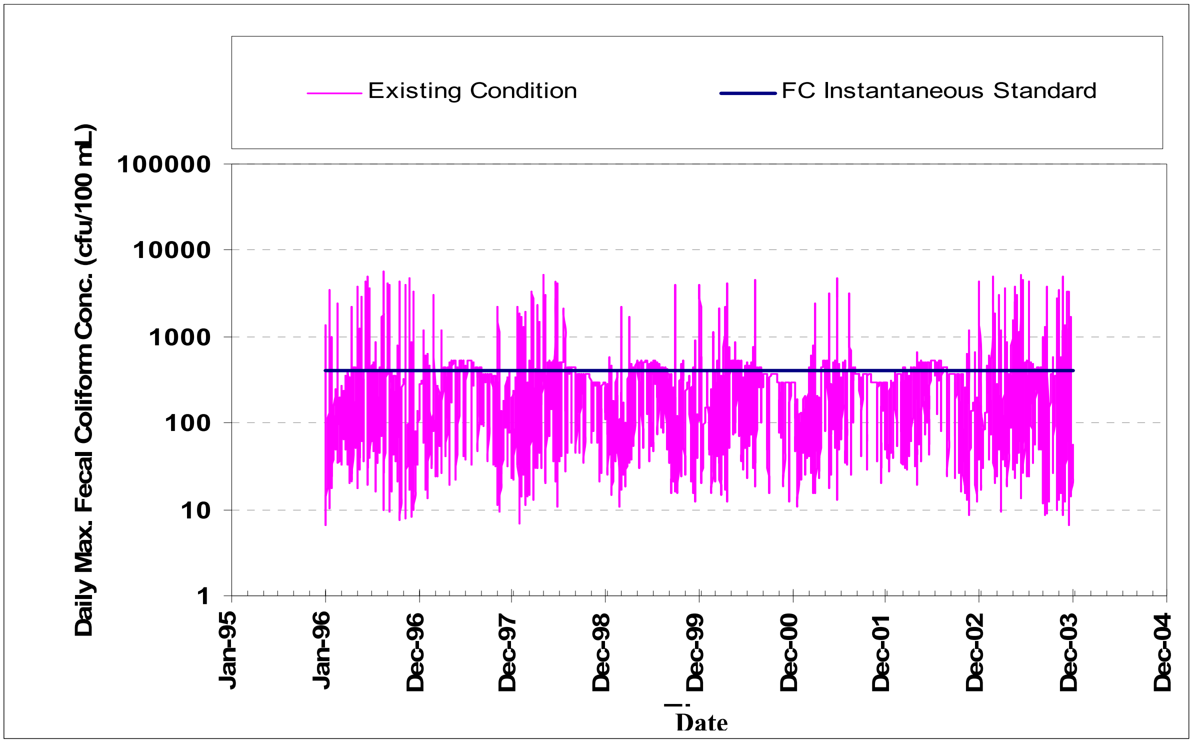


Figure F-35: South Run (Segment VAN-A19R-04) Fecal Coliform Instantaneous Existing Conditions

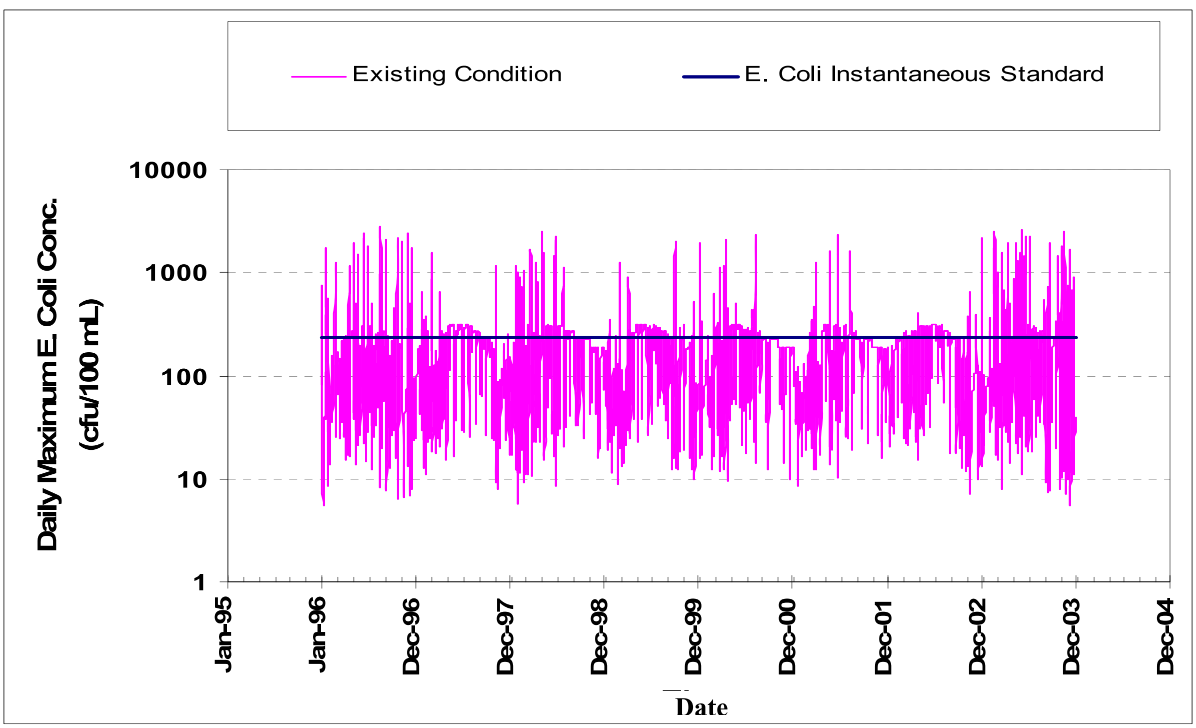


Figure F-36: South Run (Segment VAN-A19R-04) E. coli Instantaneous Existing Conditions

F.8 Popes Head Creek (Segment VAN-A23R-02)

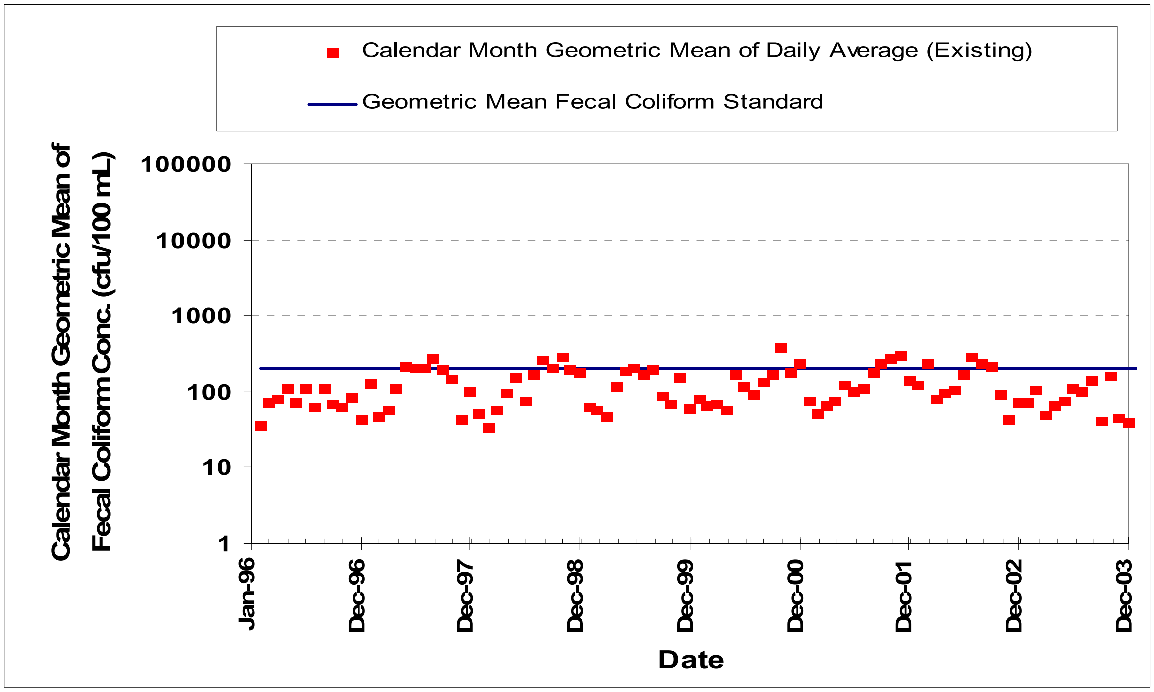


Figure F-29: Popes Head Creek (Segment VAN-A23R-02) Fecal Coliform Geometric Mean Existing Conditions

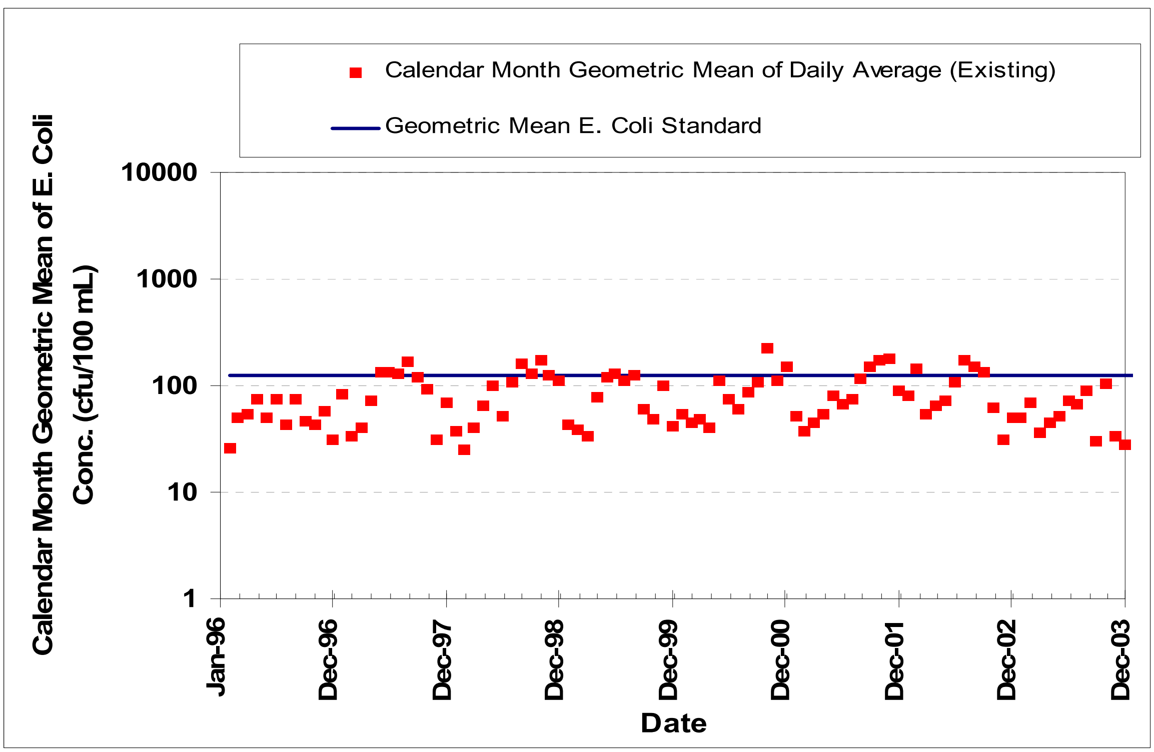


Figure F-30: Popes Head Creek (Segment VAN-A23R-02) E. coli Geometric Mean Existing Conditions

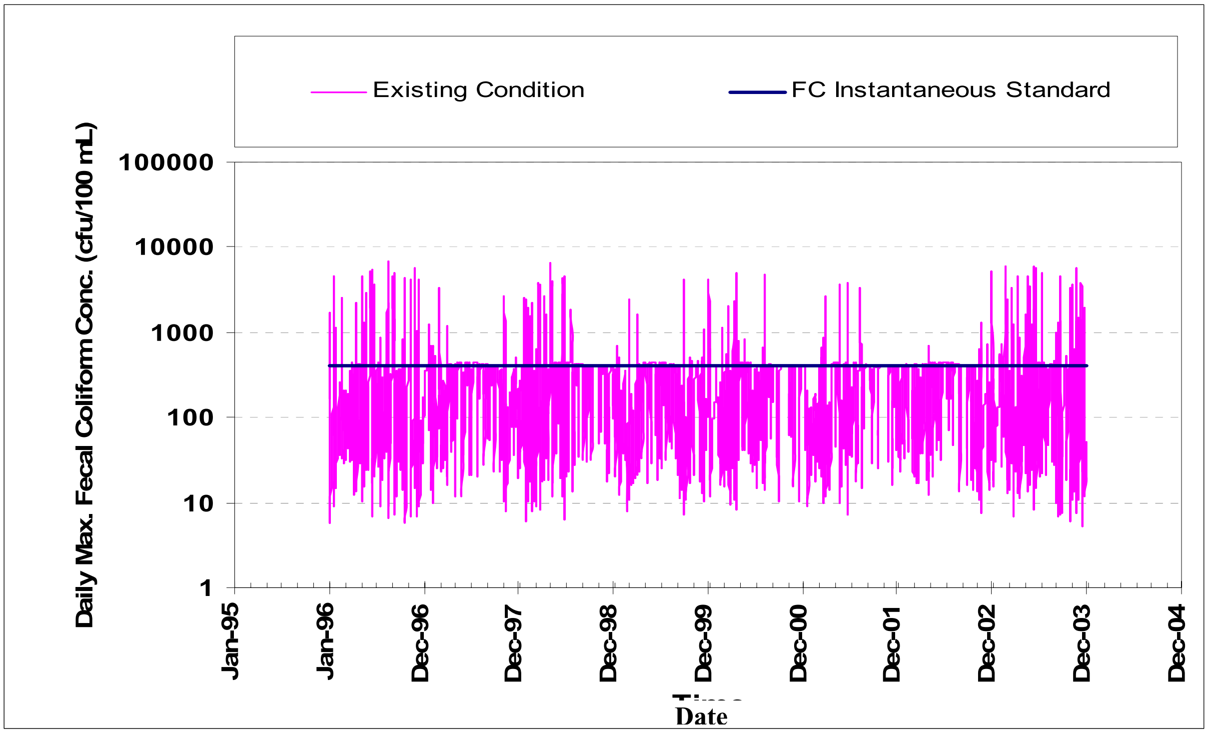


Figure F-31: Popes Head Creek (Segment VAN-A23R-02) Fecal Coliform Instantaneous Existing Conditions

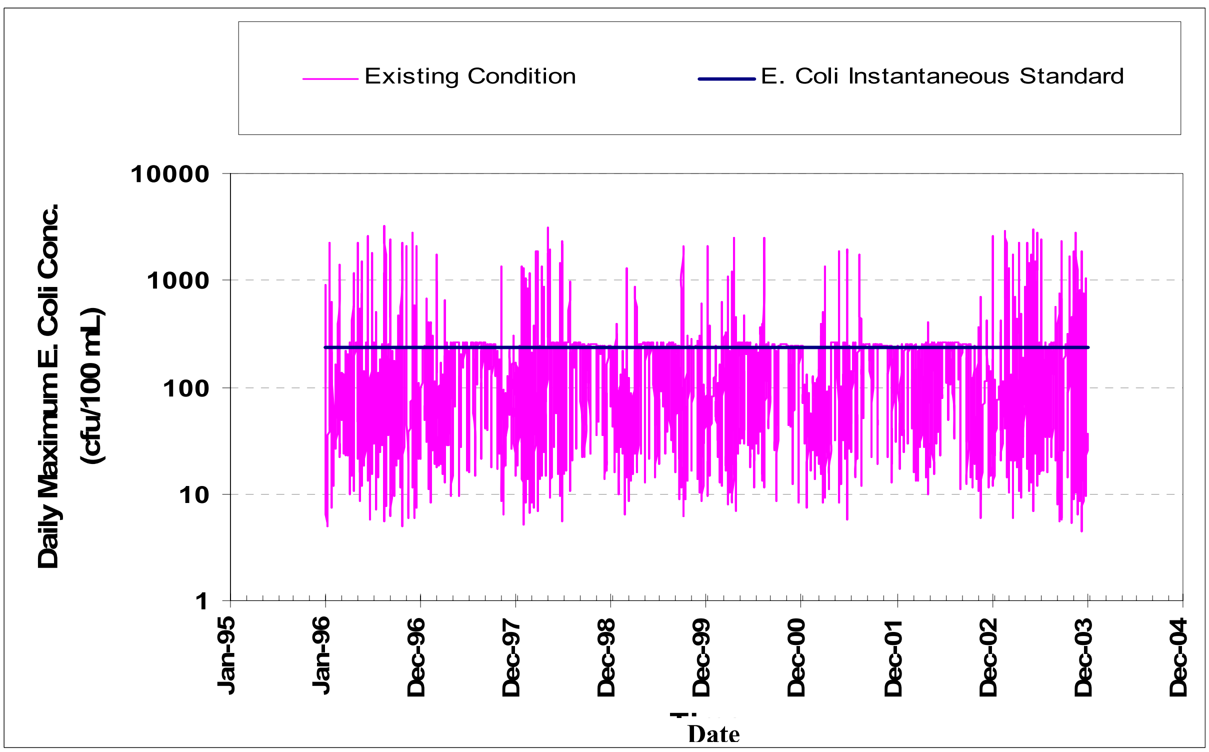


Figure F-32: Popes Head Creek (Segment VAN-A23R-02) E. coli Instantaneous Existing Conditions

F.6 Little Bull Run (Segment VAN-A21R-01)

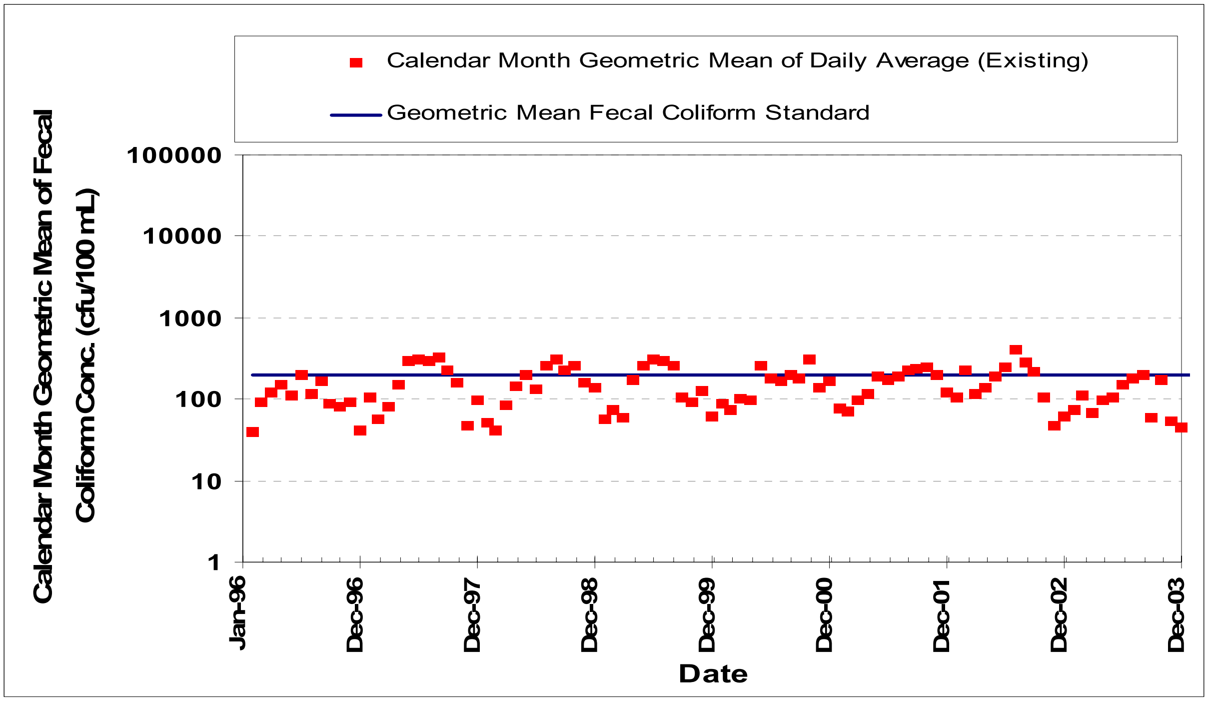


Figure F-21: Little Bull Run (Segment VAN-A21R-01) Fecal Coliform Geometric Mean Existing Conditions

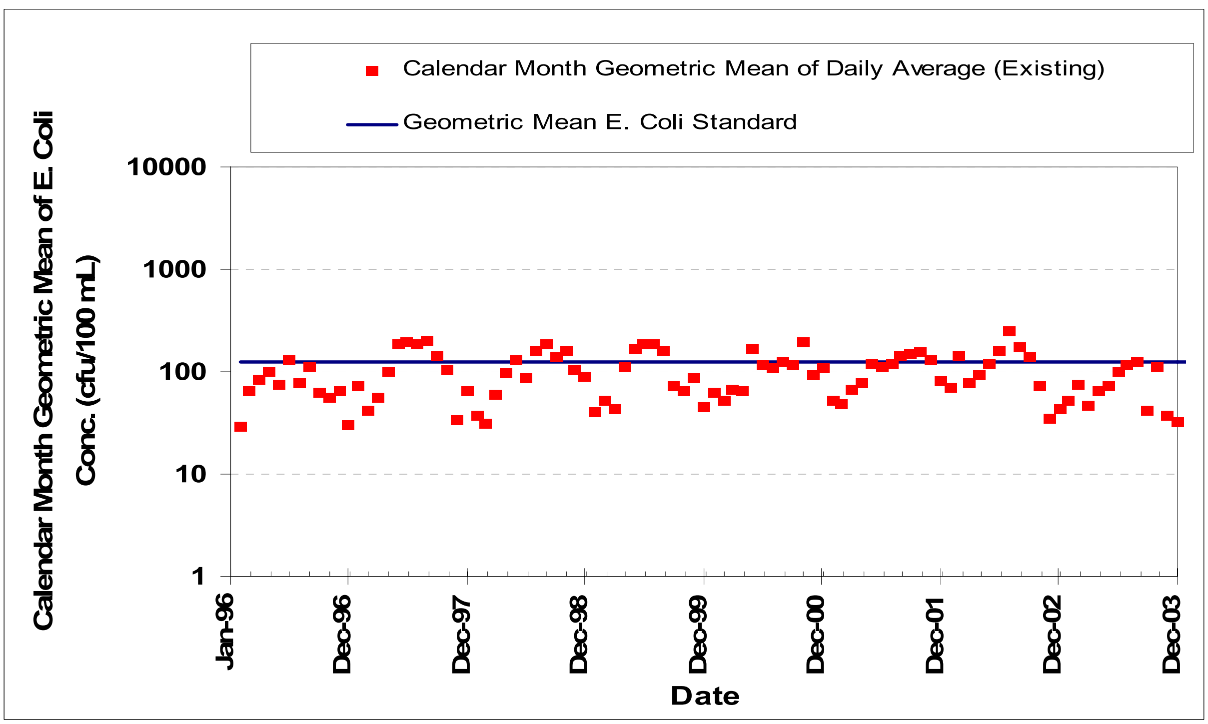


Figure F-22: Little Bull Run (Segment VAN-A21R-01) E. coli Geometric Mean Existing Conditions

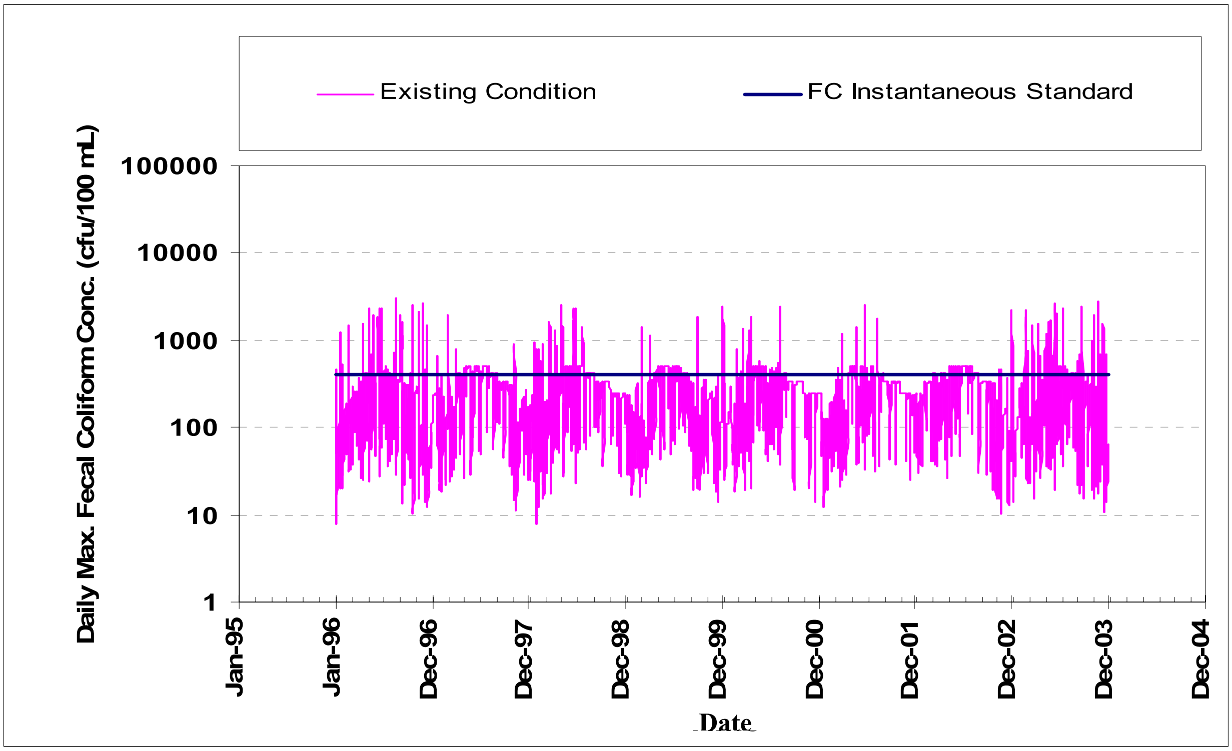


Figure F-23: Little Bull Run (Segment VAN-A21R-01) Fecal Coliform Instantaneous Existing Conditions

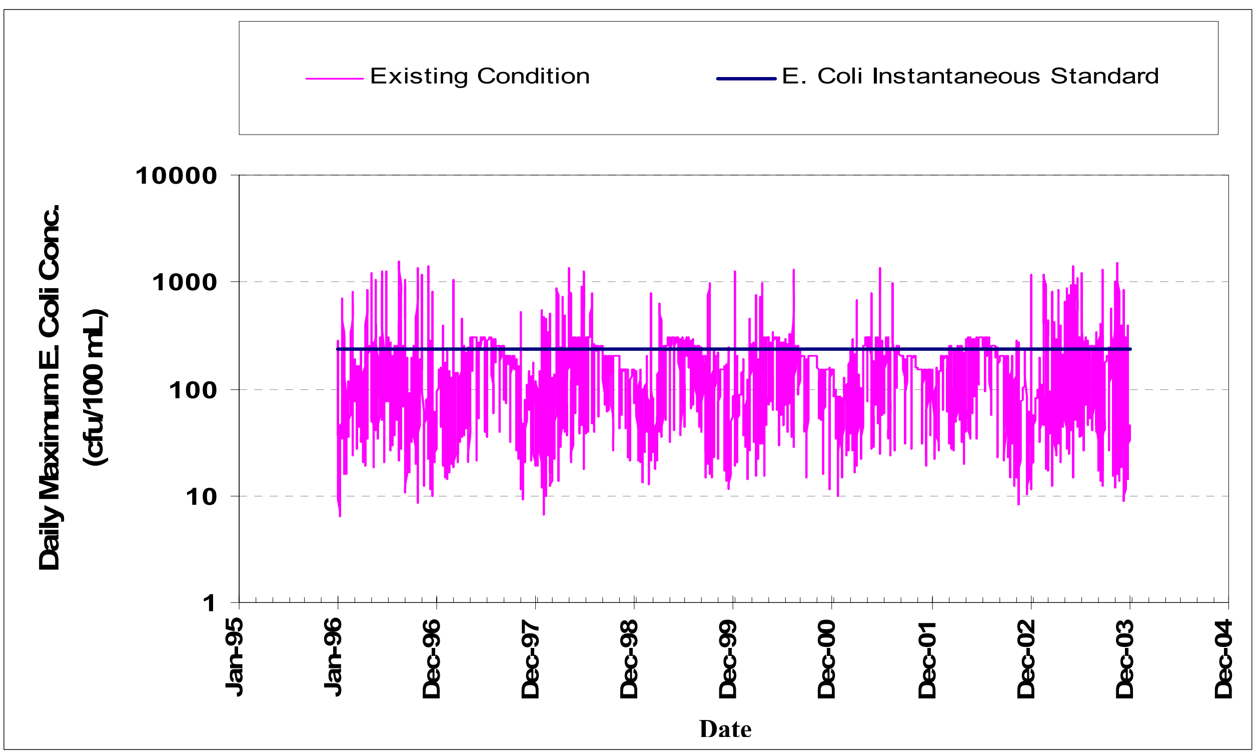


Figure F-24: Little Bull Run (Segment VAN-A21R-01) E. coli Instantaneous Existing Conditions

F.4 Bull Run (Segment VAN-A23R-01)

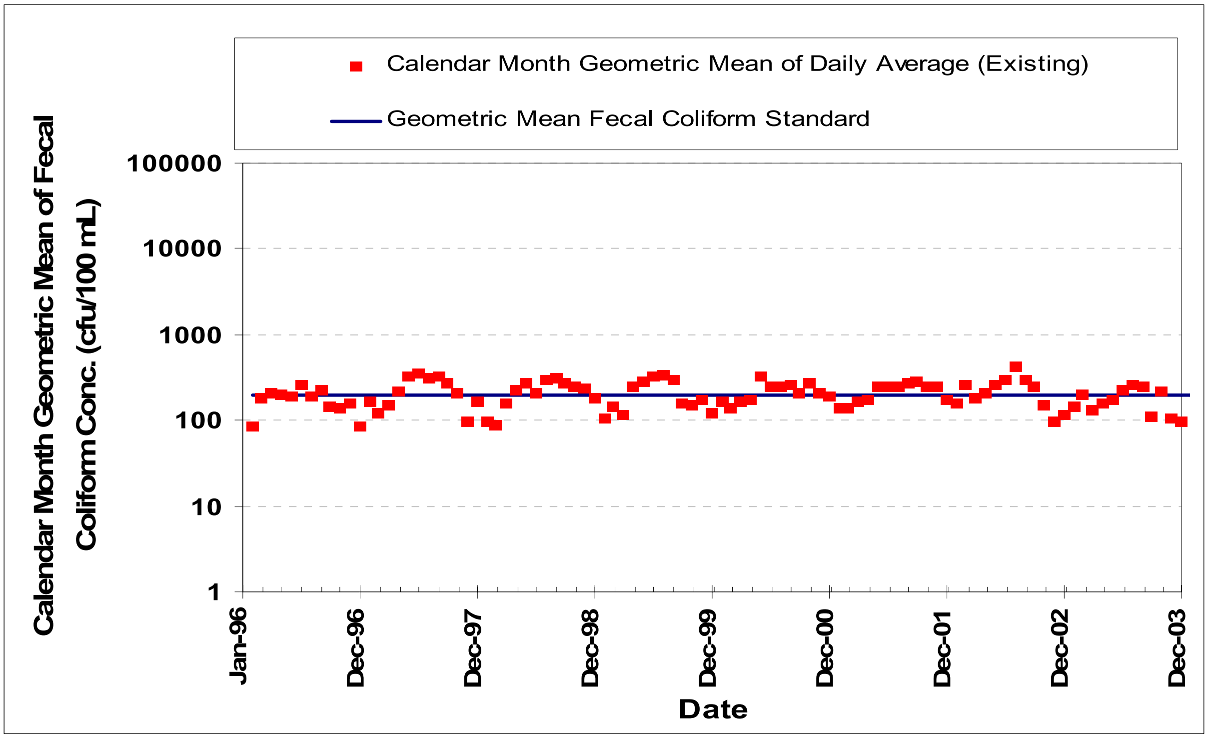


Figure F-13: Bull Run (Segment VAN-A23R-01) Fecal Coliform Geometric Mean Existing Conditions

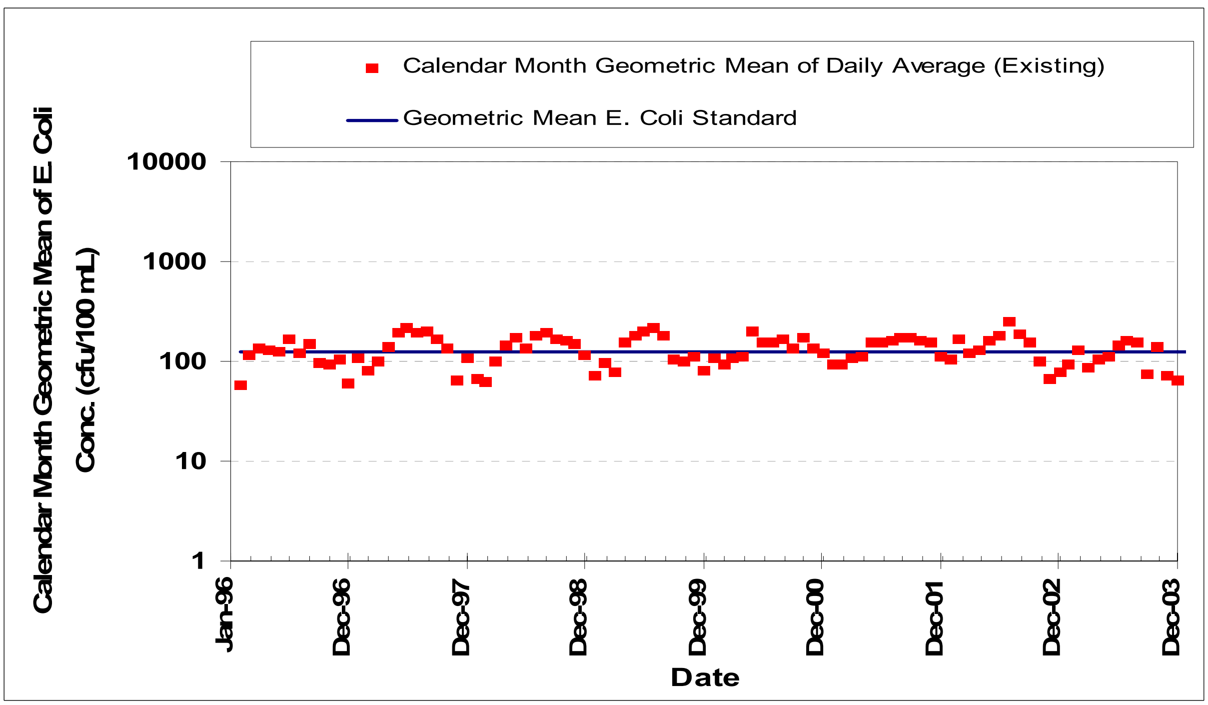


Figure F-14: Bull Run (Segment VAN-A23R-01) E. coli Geometric Mean Existing Conditions

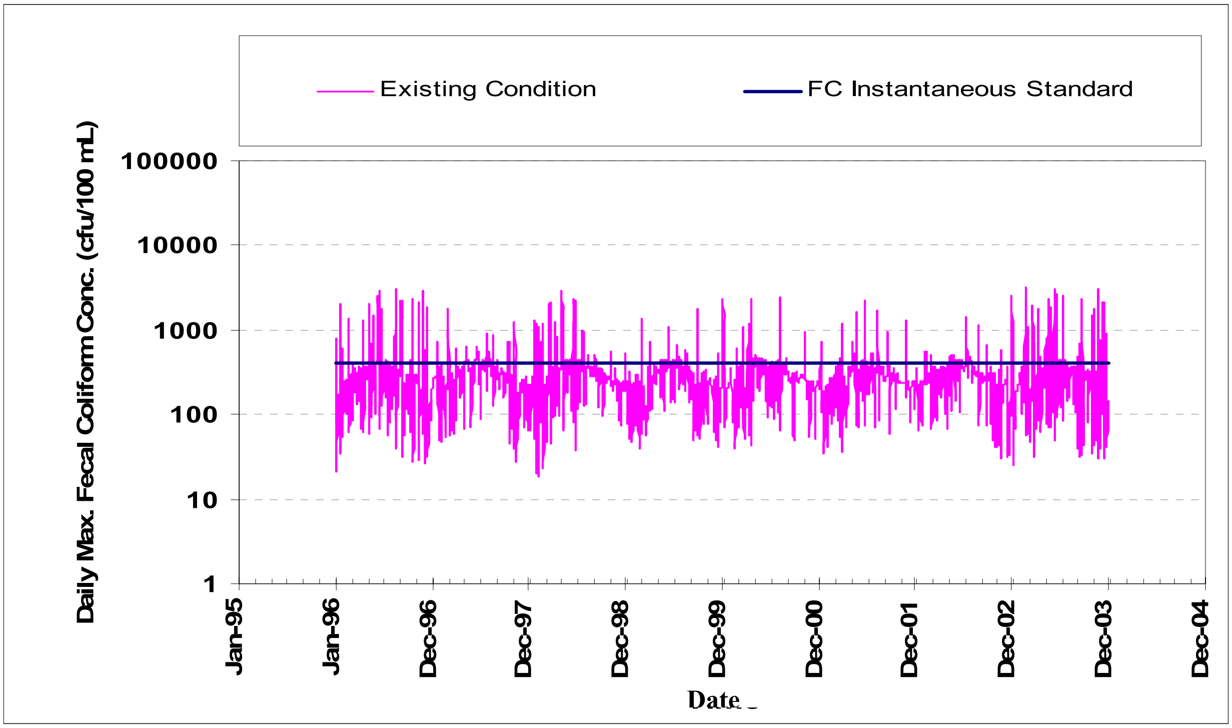


Figure F-15: Bull Run (Segment VAN-A23R-01) Fecal Coliform Instantaneous Existing Conditions

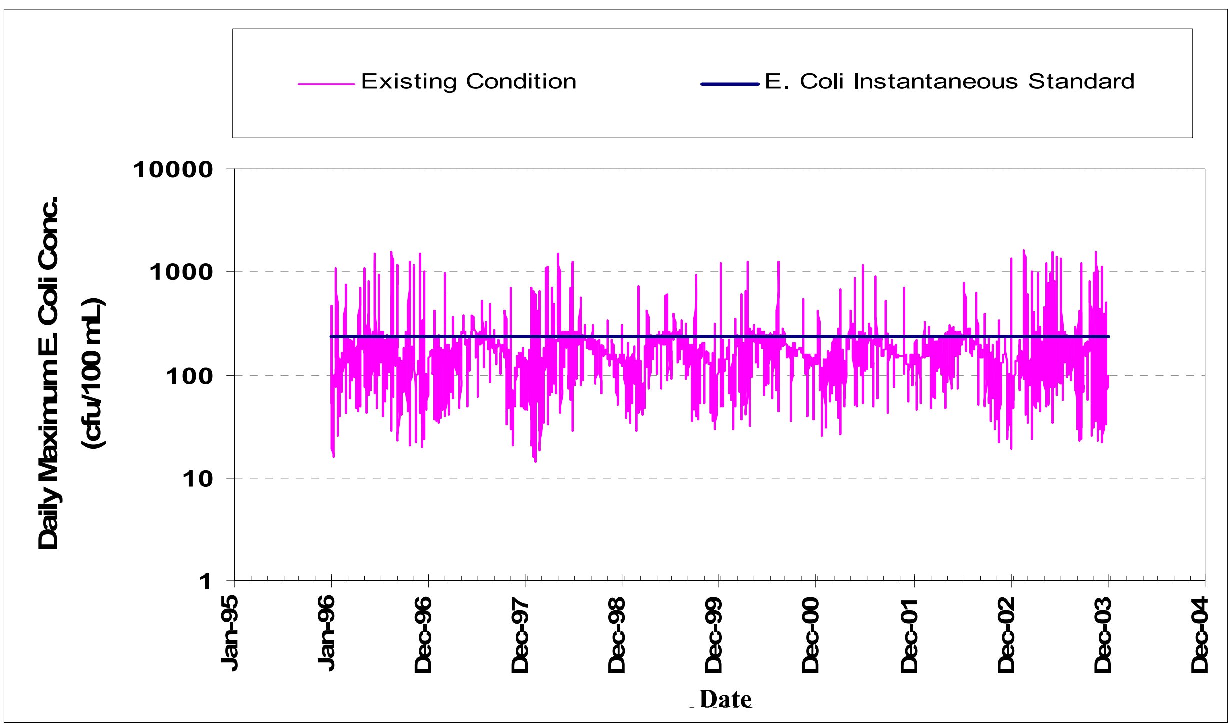


Figure F-16: Bull Run (Segment VAN-A23R-01) E. coli Instantaneous Existing Conditions

F.7 Occoquan River (Segment VAN-A20R-01)

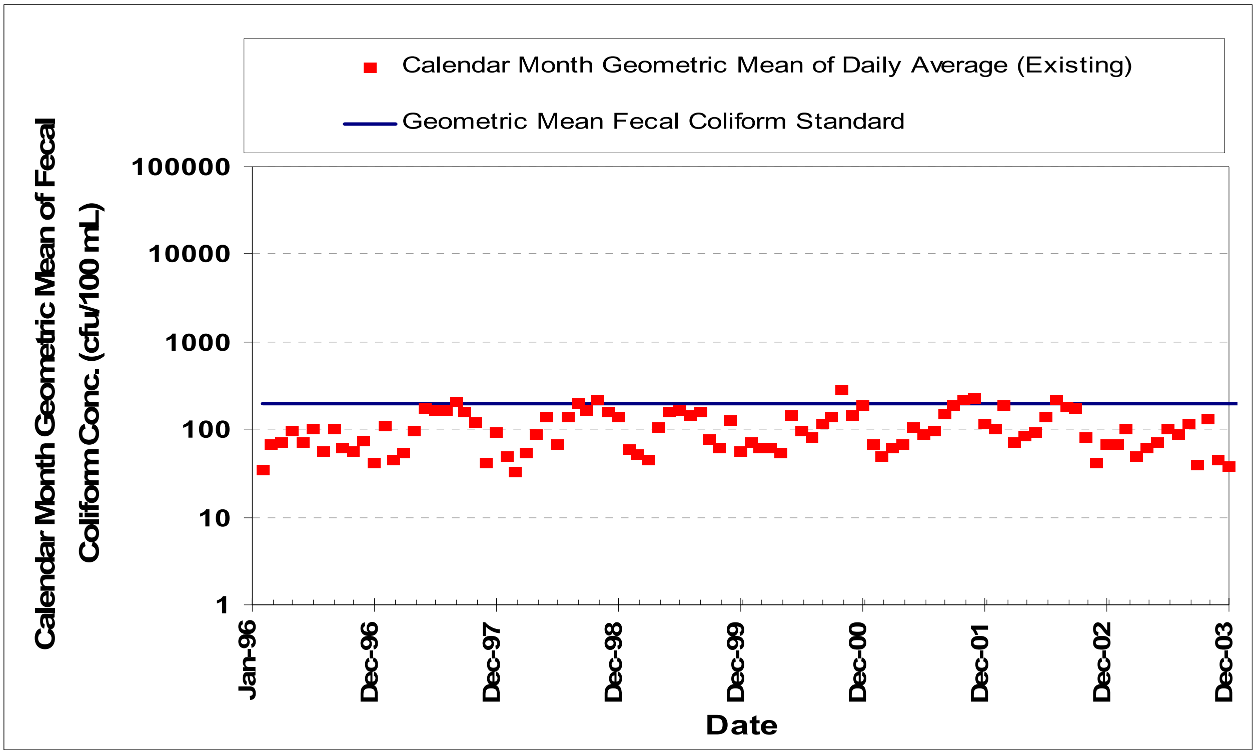


Figure F-25: Occoquan River (Segment VAN-A20R-01) Fecal Coliform Geometric Mean Existing Conditions

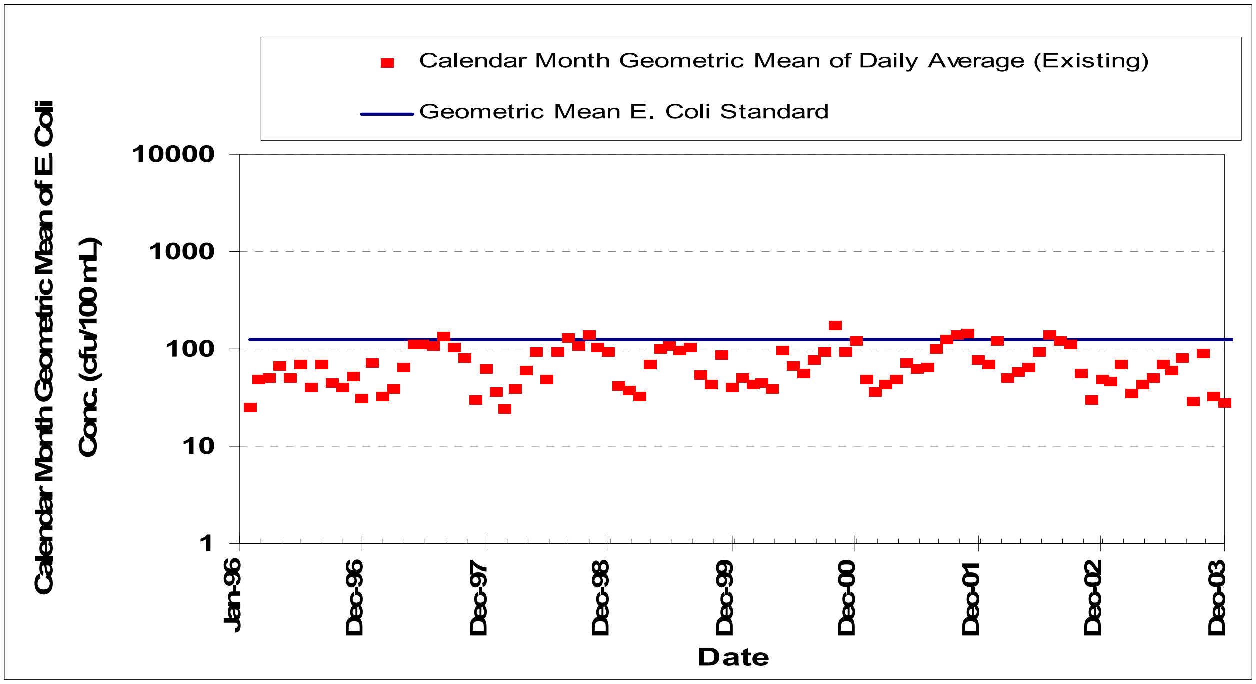


Figure F-26: Occoquan River (Segment VAN-A20R-01) E. coli Geometric Mean Existing Conditions

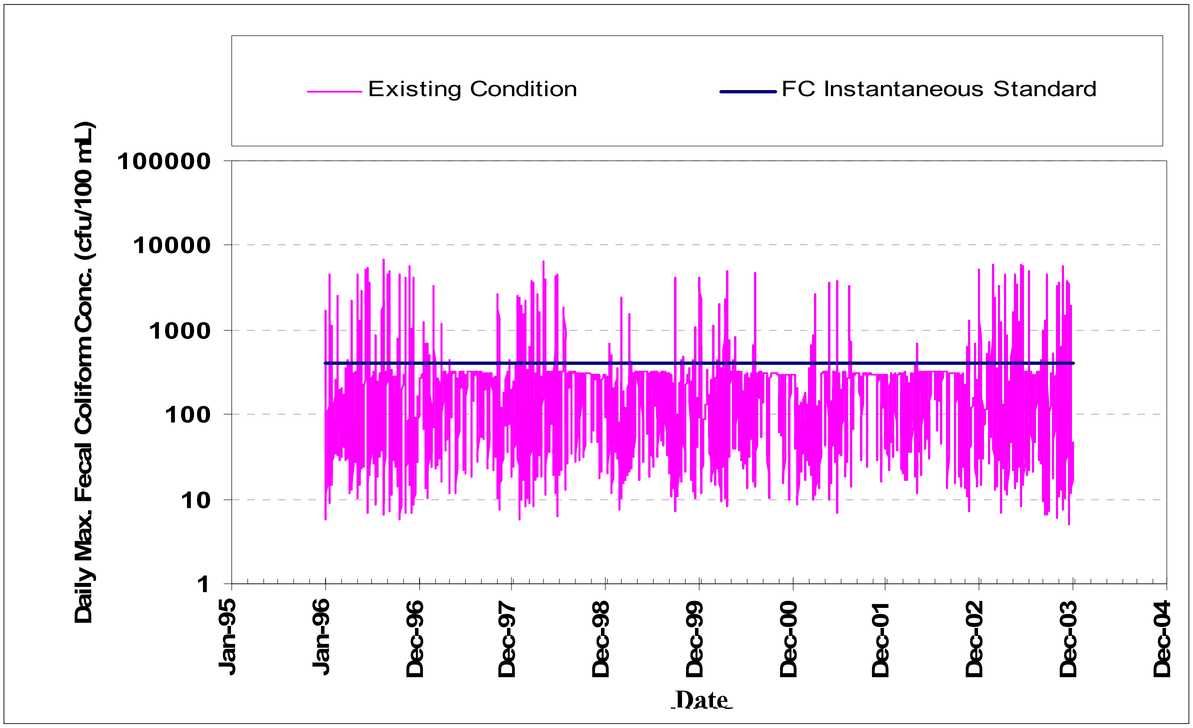


Figure F-27: Occoquan River (Segment VAN-A20R-01) Fecal Coliform Instantaneous Existing Conditions

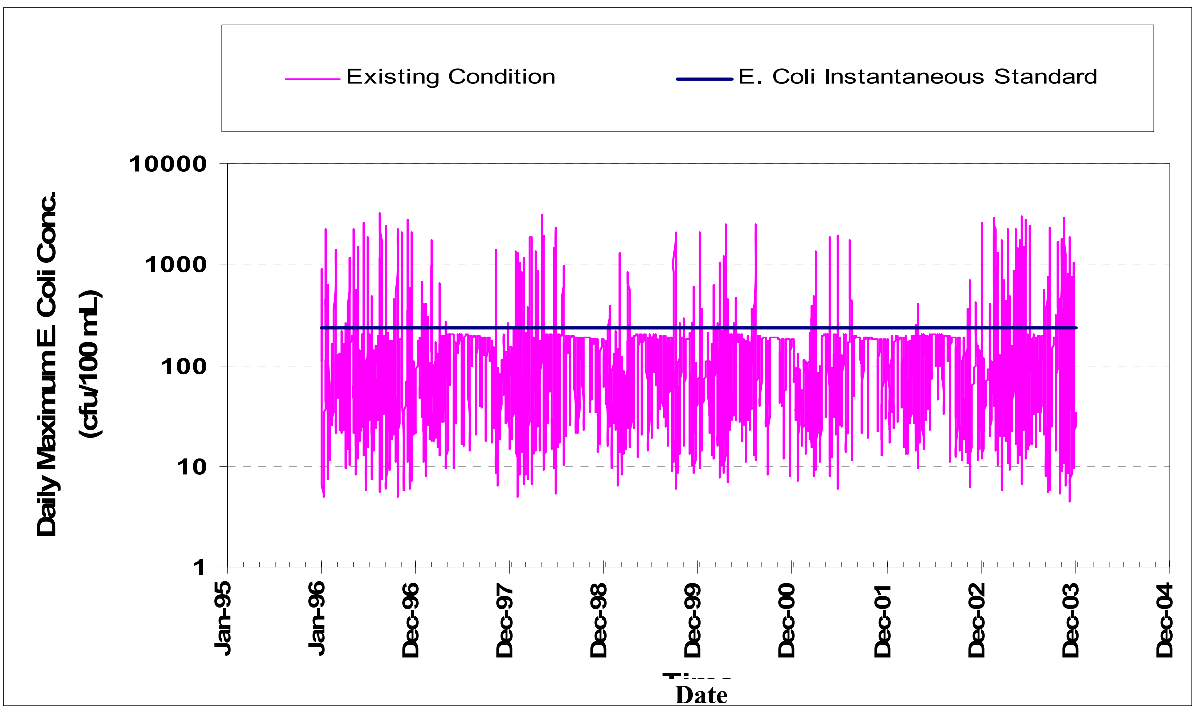


Figure F-28: Occoquan River (Segment VAN-A20R-01) E. coli Instantaneous Existing Conditions

Appendix G

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Potential sources of fecal coliform include non-point (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model calibration parameters on the simulation of flow and the violation of the fecal coliform standard in the nine impairments. For the January 1995 to December 2004 period, the model was run with 110 percent and 90 percent of calibrated values of the parameters. The scenarios that were analyzed include the following:

- 10 percent increase in LZSN
- 10 percent decrease in LZSN
- 10 percent increase in INFILT
- 10 percent decrease in INFILT
- 10 percent increase in AGWRC
- 10 percent decrease in AGWRC
- 10 percent increase in UZSN
- 10 percent decrease in UZSN
- 10 percent increase in INTFW
- 10 percent decrease in INTFW
- 10 percent increase in IRC
- 10 percent decrease in IRC
- 10 percent increase in LZETP
- 10 percent decrease in LZETP

The modeled flows for different sensitivity runs were compared with observed flows at the gage and the coefficients of determination of the hydrologic sensitivity analysis are presented in Table F-1. Based on these tables it can be seen that the calibration parameters affect the coefficient of determination in the decreasing order of AGWRC, INFILT, INTFW, IRC, UZSN, LZSN and LZETP.

The sensitivity analysis was also performed for two water quality parameters, WSQOP and FSTDEC, by simulating the fecal coliform concentrations for 120 percent and 80 percent of their calibrated values. The rate of violation of the Monthly Geometric Mean Water Quality Standard was determined for each scenario and compared with the rate of violation under the water quality calibration run. The changes in the rate of violation are presented in Table F-2. The results of the sensitivity analysis show that WSQOP has a more pronounced effect on the violation of the water quality standards than FSTDEC.

Table G-1: Sensitivity Analysis: Variation in Coefficient of Determination With Respect to Variation in Parameters For Simulation Period 1996-2003

Parameter	Coefficient of Determination	
	+10% change in parameter	-10% change in parameter
LZSN	0.805	0.801
INFILT	0.804	0.801
AGWRC	0.802	0.803
UZSN	0.804	0.802
INTFW	0.805	0.801
IRC	0.802	0.803
LZETP	0.803	0.803
Calibrated Parameters 0.803		

Table G-2: Sensitivity Analysis: Change in Violation Rate From 20% Change in Calibration Parameter Values

	WSQOP		FSTDEC	
Segment #	20%	-20%	20%	-20%
Little Bull Run (Segment. No. 23)	-5.0%	0.0%	0.0%	0.0%
Popes Head (Segment No. 5)	-1.7%	0.0%	0.0%	0.0%
Bull Run (Segment No. 4)	0.0%	1.7%	0.0%	0.0%
Broad Run (Segment No. 42)	0.0%	0.0%	0.0%	0.0%
Broad Run (Segment No. 40)	0.0%	1.7%	0.0%	0.0%
South Run (Segment No. 47)	-1.7%	0.0%	0.0%	0.0%
Broad Run (Segment No. 33)	-3.3%	0.0%	0.0%	0.0%
Kettle Run (Segment No. 49)	-3.3%	1.7%	0.0%	0.0%

Appendix H

Load Reduction Scenarios under 30-day Geometric Mean and Instantaneous Standards for E. c*oli*

Table H-1: Broad Run (VAN-A19R-01) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*							
Scenario	**Septics & Pipes (%)**	**Direct Cattle (%)**	**NPS-Agriculture (%)**	**NPS-Urban (%)**	**Direct Wildlife (%)**	**Exceedence of Geometric Mean E. *coli* Standard (%)**	**Exceedence of Instantaneous E. *coli* Standard (%)**
0	0	0	0	0	0	22%	70%
1	100	0	0	0	0	22%	70%
2	100	50	0	0	0	14%	70%
3	100	100	0	0	0	9%	70%
4	100	100	100	100	0	0%	0%
5	100	100	0	0	50	8%	70%
6	100	100	0	0	75	8%	70%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	85	85	0	0%	0%

Table H-1: Broad Run (VAN-A19R-02) Load Reduction Scenarios under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*							
Scenario	**Septics & Pipes (%)**	**Direct Cattle (%)**	**NPS-Agriculture (%)**	**NPS-Urban (%)**	**Direct Wildlife (%)**	**Exceedence of Geometric Mean E. *coli* Standard (%)**	**Exceedence of Instantaneous E. *coli* Standard (%)**
0	0	0	0	0	0	53%	94%
1	100	0	0	0	0	52%	94%
2	100	50	0	0	0	41%	90%
3	100	100	0	0	0	27%	84%
4	100	100	100	100	0	25%	84%
5	100	100	0	0	50	1%	30%
6	100	100	0	0	75	0%	30%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	90	90	60	0%	0%

Table H-3: Broad Run (VAN-A19R-05) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*							
Scenario	**Septics & Pipes (%)**	**Direct Cattle (%)**	**NPS-Agriculture (%)**	**NPS-Urban (%)**	**Direct Wildlife (%)**	**Exceedence of Geometric Mean E. *coli* Standard (%)**	**Exceedence of Instantaneous E. *coli* Standard (%)**
0	0	0	0	0	0	43%	94%
1	100	0	0	0	0	43%	94%
2	100	50	0	0	0	32%	87%
3	100	100	0	0	0	23%	81%
4	100	100	100	100	0	19%	81%
5	100	100	0	0	50	0%	27%
6	100	100	0	0	75	0%	27%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	95	95	80	0%	0%

Table H-4: South Run (VAN-A19R-04) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*							
Scenario	**Septics & Pipes (%)**	**Direct Cattle (%)**	**NPS-Agriculture (%)**	**NPS-Urban (%)**	**Direct Wildlife (%)**	**Exceedence of Geometric Mean E. *coli* Standard (%)**	**Exceedence of Instantaneous E. *coli* Standard (%)**
0	0	0	0	0	0	9%	33%
1	100	0	0	0	0	8%	33%
2	100	50	0	0	0	0%	33%
3	100	100	0	0	0	0%	33%
4	100	100	100	100	0	0%	0%
5	100	100	0	0	50	0%	33%
6	100	100	0	0	75	0%	33%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	95	95	50	0%	0%

Table H-5: Kettle Run (VAN-A19R-03) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*							
Scenario	**Septics & Pipes (%)**	**Direct Cattle (%)**	**NPS-Agriculture (%)**	**NPS-Urban (%)**	**Direct Wildlife (%)**	**Exceedence of Geometric Mean E. *coli* Standard (%)**	**Exceedence of Instantaneous E. *coli* Standard (%)**
0	0	0	0	0	0	60%	97%
1	100	0	0	0	0	60%	97%
2	100	50	0	0	0	43%	94%
3	100	100	0	0	0	1%	33%
4	100	100	100	100	0	1%	0%
5	100	100	0	0	50	0%	33%
6	100	100	0	0	75	0%	33%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	95	95	50	0%	0%

Table H-6: Popes Head Creek (VAN-A23R-02) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*							
Scenario	**Septics & Pipes (%)**	**Direct Cattle (%)**	**NPS-Agriculture (%)**	**NPS-Urban (%)**	**Direct Wildlife (%)**	**Exceedence of Geometric Mean E. *coli* Standard (%)**	**Exceedence of Instantaneous E. *coli* Standard (%)**
0	0	0	0	0	0	19%	81%
1	100	0	0	0	0	18%	81%
2	100	50	0	0	0	13%	74%
3	100	100	0	0	0	11%	33%
4	100	100	100	100	0	11%	0%
5	100	100	0	0	50	0%	33%
6	100	100	0	0	75	0%	33%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	95	95	48	0%	0%

Table H-7: Little Bull Run (VAN-A21R-01) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	26%	90%
1	100	0	0	0	0	26%	90%
2	100	50	0	0	0	1%	30%
3	100	100	0	0	0	0%	30%
4	100	100	100	100	0	0%	0%
5	100	100	0	0	50	0%	30%
6	100	100	0	0	75	0%	30%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	90	90	0	0%	0%

Table H-8: Bull Run (VAN-A23R-01) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	11%	37%
1	100	0	0	0	0	11%	37%
2	100	50	0	0	0	0%	37%
3	100	100	0	0	0	0%	37%
4	100	100	100	100	0	0%	7%
5	100	100	0	0	50	0%	37%
6	100	100	0	0	75	0%	33%
7	100	100	95	95	75	0%	0%
8 (TMDL)	100	100	90	90	0	0%	0%

Table H-9 Occoquan River (VAN-A20R-01) Load Reduction Scenario under 30-Day Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	7%	37%
1	100	0	0	0	0	7%	37%
2	100	50	0	0	0	4%	37%
3	100	100	0	0	0	3%	37%
4	100	100	100	100	0	0%	7%
5	100	100	0	0	50	2%	37%
6	100	100	0	0	75	2%	37%
7	100	100	95	95	75	0%	10%
8 (TMDL)	100	100	95	95	0	0%	0%

Appendix I

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

H.1 Fecal Coliform Monthly Loads- Existing Conditions

Table I-1: Broad Run - 34 (VAN-A19R-01) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	1.36E+11	3.19E+10	2.38E+11	1.35E+12	4.67E+11	3.70E+09	4.32E+10	1.24E+12
2	1.12E+11	3.62E+10	2.26E+11	1.30E+12	4.34E+11	3.03E+09	4.13E+10	1.15E+12
3	1.51E+11	4.91E+10	2.53E+11	1.29E+12	4.59E+11	4.12E+09	4.19E+10	1.19E+12
4	1.17E+11	3.13E+10	1.49E+11	6.02E+11	2.24E+11	3.23E+09	2.08E+10	5.64E+11
5	1.42E+11	4.13E+10	2.54E+11	1.42E+12	5.13E+11	3.88E+09	4.37E+10	1.30E+12
6	1.40E+11	5.30E+10	3.46E+11	2.13E+12	7.14E+11	3.80E+09	6.59E+10	1.92E+12
7	1.21E+11	2.78E+10	1.26E+11	3.41E+11	1.20E+11	3.38E+09	1.37E+10	2.97E+11
8	9.49E+10	2.66E+10	1.33E+11	5.82E+11	2.18E+11	2.63E+09	1.85E+10	5.41E+11
9	1.25E+11	4.17E+10	2.24E+11	1.18E+12	4.03E+11	3.44E+09	3.91E+10	1.09E+12
10	7.77E+10	2.56E+10	1.31E+11	6.54E+11	2.20E+11	2.13E+09	2.18E+10	5.85E+11
11	9.07E+10	2.33E+10	1.57E+11	8.79E+11	3.24E+11	2.48E+09	2.73E+10	8.19E+11
12	1.06E+11	2.16E+10	1.82E+11	1.03E+12	3.46E+11	2.90E+09	3.36E+10	9.19E+11

Table I-2: Broad Run - 40 (VAN-A19R-02) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	3.89E+10	7.60E+09	5.27E+10	3.12E+11	3.08E+10	1.48E+08	1.39E+09	0.00E+00
2	3.21E+10	8.62E+09	5.02E+10	3.01E+11	2.86E+10	1.21E+08	1.33E+09	0.00E+00
3	4.31E+10	1.17E+10	5.61E+10	2.99E+11	3.02E+10	1.65E+08	1.35E+09	0.00E+00
4	3.34E+10	7.46E+09	3.31E+10	1.39E+11	1.48E+10	1.29E+08	6.69E+08	0.00E+00
5	4.06E+10	9.85E+09	5.63E+10	3.29E+11	3.39E+10	1.55E+08	1.40E+09	0.00E+00
6	4.03E+10	1.26E+10	7.66E+10	4.94E+11	4.71E+10	1.52E+08	2.12E+09	0.00E+00
7	3.48E+10	6.63E+09	2.79E+10	7.90E+10	7.94E+09	1.35E+08	4.40E+08	0.00E+00
8	2.72E+10	6.33E+09	2.95E+10	1.35E+11	1.44E+10	1.05E+08	5.95E+08	0.00E+00
9	3.60E+10	9.94E+09	4.97E+10	2.74E+11	2.65E+10	1.37E+08	1.26E+09	0.00E+00
10	2.23E+10	6.09E+09	2.90E+10	1.52E+11	1.45E+10	8.50E+07	7.02E+08	0.00E+00
11	2.60E+10	5.56E+09	3.48E+10	2.04E+11	2.14E+10	9.91E+07	8.78E+08	0.00E+00
12	3.05E+10	5.16E+09	4.04E+10	2.40E+11	2.28E+10	1.16E+08	1.08E+09	0.00E+00

Table I-3: Broad Run - 42 (VAN-A19R-05) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	3.55E+10	1.10E+10	1.01E+11	1.12E+11	4.20E+10	2.46E+07	0.00E+00	0.00E+00
2	2.92E+10	1.25E+10	9.61E+10	1.08E+11	3.91E+10	2.02E+07	0.00E+00	0.00E+00
3	3.93E+10	1.70E+10	1.07E+11	1.07E+11	4.12E+10	2.74E+07	0.00E+00	0.00E+00
4	3.05E+10	1.08E+10	6.33E+10	5.01E+10	2.01E+10	2.15E+07	0.00E+00	0.00E+00
5	3.70E+10	1.43E+10	1.08E+11	1.18E+11	4.62E+10	2.58E+07	0.00E+00	0.00E+00
6	3.67E+10	1.83E+10	1.47E+11	1.78E+11	6.42E+10	2.53E+07	0.00E+00	0.00E+00
7	3.17E+10	9.61E+09	5.34E+10	2.84E+10	1.08E+10	2.25E+07	0.00E+00	0.00E+00

Table I-3: Broad Run - 42 (VAN-A19R-05) Fecal Coliform Load: Existing Condition (counts/ month)								
8	2.48E+10	9.18E+09	5.64E+10	4.85E+10	1.96E+10	1.75E+07	0.00E+00	0.00E+00
9	3.28E+10	1.44E+10	9.52E+10	9.86E+10	3.62E+10	2.29E+07	0.00E+00	0.00E+00
10	2.03E+10	8.82E+09	5.56E+10	5.45E+10	1.97E+10	1.42E+07	0.00E+00	0.00E+00
11	2.37E+10	8.05E+09	6.66E+10	7.32E+10	2.91E+10	1.65E+07	0.00E+00	0.00E+00
12	2.78E+10	7.47E+09	7.75E+10	8.62E+10	3.11E+10	1.93E+07	0.00E+00	0.00E+00

Table I-4: Bull Run - 9 (VAN-A23R-01) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial /Industrial	Water/Wetland	Other Urban	High Density Residential
1	2.23E+10	6.38E+07	4.48E+09	1.39E+12	4.65E+10	7.73E+08	1.48E+10	1.11E+12
2	1.83E+10	7.22E+07	4.27E+09	1.34E+12	4.33E+10	6.34E+08	1.41E+10	1.02E+12
3	2.47E+10	9.82E+07	4.77E+09	1.33E+12	4.57E+10	8.62E+08	1.43E+10	1.06E+12
4	1.91E+10	6.25E+07	2.81E+09	6.22E+11	2.23E+10	6.75E+08	7.12E+09	5.03E+11
5	2.32E+10	8.26E+07	4.79E+09	1.47E+12	5.11E+10	8.10E+08	1.49E+10	1.16E+12
6	2.30E+10	1.06E+08	6.52E+09	2.21E+12	7.11E+10	7.95E+08	2.25E+10	1.71E+12
7	1.99E+10	5.56E+07	2.37E+09	3.53E+11	1.20E+10	7.07E+08	4.68E+09	2.65E+11
8	1.56E+10	5.31E+07	2.50E+09	6.02E+11	2.17E+10	5.49E+08	6.34E+09	4.82E+11
9	2.06E+10	8.34E+07	4.23E+09	1.22E+12	4.01E+10	7.18E+08	1.34E+10	9.69E+11
10	1.27E+10	5.11E+07	2.47E+09	6.76E+11	2.19E+10	4.45E+08	7.47E+09	5.22E+11
11	1.49E+10	4.66E+07	2.96E+09	9.09E+11	3.23E+10	5.19E+08	9.35E+09	7.30E+11
12	1.75E+10	4.33E+07	3.44E+09	1.07E+12	3.45E+10	6.07E+08	1.15E+10	8.19E+11

Table I-5: Kettle Run (VAN-A19R-03) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	2.95E+10	2.30E+10	4.73E+10	6.46E+11	2.35E+10	3.05E+08	8.03E+09	3.14E+10
2	2.43E+10	2.61E+10	4.50E+10	6.23E+11	2.19E+10	2.50E+08	7.68E+09	2.91E+10
3	3.27E+10	3.55E+10	5.03E+10	6.18E+11	2.31E+10	3.40E+08	7.78E+09	3.02E+10
4	2.53E+10	2.26E+10	2.97E+10	2.88E+11	1.13E+10	2.66E+08	3.87E+09	1.43E+10
5	3.07E+10	2.99E+10	5.05E+10	6.82E+11	2.58E+10	3.20E+08	8.12E+09	3.31E+10
6	3.05E+10	3.83E+10	6.88E+10	1.02E+12	3.59E+10	3.14E+08	1.22E+10	4.86E+10
7	2.63E+10	2.01E+10	2.50E+10	1.64E+11	6.06E+09	2.79E+08	2.54E+09	7.54E+09
8	2.06E+10	1.92E+10	2.64E+10	2.79E+11	1.10E+10	2.17E+08	3.44E+09	1.37E+10
9	2.72E+10	3.01E+10	4.46E+10	5.67E+11	2.03E+10	2.84E+08	7.27E+09	2.75E+10
10	1.69E+10	1.85E+10	2.61E+10	3.14E+11	1.11E+10	1.76E+08	4.06E+09	1.48E+10
11	1.97E+10	1.68E+10	3.12E+10	4.21E+11	1.63E+10	2.05E+08	5.08E+09	2.08E+10
12	2.31E+10	1.56E+10	3.63E+10	4.96E+11	1.74E+10	2.40E+08	6.24E+09	2.33E+10

Table I-6:Little Bull Run (VAN-A21R-01) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	3.74E+10	5.91E+09	3.93E+10	2.63E+11	5.04E+10	2.41E+08	2.32E+10	2.99E+11
2	3.09E+10	6.70E+09	3.74E+10	2.54E+11	4.69E+10	1.98E+08	2.22E+10	2.77E+11
3	4.15E+10	9.10E+09	4.18E+10	2.52E+11	4.95E+10	2.69E+08	2.25E+10	2.88E+11
4	3.22E+10	5.80E+09	2.46E+10	1.17E+11	2.42E+10	2.11E+08	1.12E+10	1.36E+11
5	3.91E+10	7.66E+09	4.20E+10	2.78E+11	5.54E+10	2.53E+08	2.35E+10	3.15E+11
6	3.88E+10	9.82E+09	5.71E+10	4.17E+11	7.71E+10	2.48E+08	3.54E+10	4.63E+11

Table I-6:Little Bull Run (VAN-A21R-01) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
7	3.35E+10	5.16E+09	2.08E+10	6.67E+10	1.30E+10	2.21E+08	7.36E+09	7.18E+10
8	2.62E+10	4.92E+09	2.20E+10	1.14E+11	2.36E+10	1.71E+08	9.96E+09	1.31E+11
9	3.46E+10	7.73E+09	3.71E+10	2.31E+11	4.35E+10	2.24E+08	2.10E+10	2.62E+11
10	2.14E+10	4.73E+09	2.17E+10	1.28E+11	2.37E+10	1.39E+08	1.17E+10	1.41E+11
11	2.50E+10	4.32E+09	2.59E+10	1.72E+11	3.50E+10	1.62E+08	1.47E+10	1.98E+11
12	2.94E+10	4.01E+09	3.02E+10	2.02E+11	3.74E+10	1.89E+08	1.80E+10	2.22E+11

Table I-7: Occoquan River (VAN-A20R-01) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	4.03E+10	5.84E+09	1.57E+10	2.05E+12	2.34E+11	9.15E+08	3.33E+10	1.88E+12
2	3.32E+10	6.61E+09	1.49E+10	1.97E+12	2.18E+11	7.49E+08	3.19E+10	1.74E+12
3	4.47E+10	8.99E+09	1.67E+10	1.96E+12	2.30E+11	1.02E+09	3.23E+10	1.81E+12
4	3.46E+10	5.72E+09	9.85E+09	9.12E+11	1.12E+11	7.98E+08	1.61E+10	8.55E+11
5	4.21E+10	7.56E+09	1.68E+10	2.16E+12	2.57E+11	9.58E+08	3.37E+10	1.98E+12
6	4.17E+10	9.70E+09	2.28E+10	3.24E+12	3.58E+11	9.40E+08	5.08E+10	2.91E+12
7	3.60E+10	5.09E+09	8.30E+09	5.18E+11	6.03E+10	8.36E+08	1.06E+10	4.51E+11
8	2.82E+10	4.86E+09	8.78E+09	8.83E+11	1.09E+11	6.50E+08	1.43E+10	8.20E+11
9	3.73E+10	7.63E+09	1.48E+10	1.80E+12	2.02E+11	8.50E+08	3.02E+10	1.65E+12
10	2.31E+10	4.67E+09	8.65E+09	9.92E+11	1.10E+11	5.26E+08	1.68E+10	8.87E+11
11	2.69E+10	4.26E+09	1.04E+10	1.33E+12	1.62E+11	6.13E+08	2.11E+10	1.24E+12
12	3.16E+10	3.96E+09	1.21E+10	1.57E+12	1.74E+11	7.18E+08	2.59E+10	1.39E+12

Table I-8: Popes Head (VAN-A23R-02) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	1.45E+11	3.69E+10	1.69E+11	2.70E+12	1.63E+12	5.91E+09	1.94E+11	1.10E+13
2	1.20E+11	4.18E+10	1.61E+11	2.60E+12	1.52E+12	4.84E+09	1.86E+11	1.02E+13
3	1.61E+11	5.67E+10	1.80E+11	2.58E+12	1.60E+12	6.58E+09	1.88E+11	1.06E+13
4	1.25E+11	3.61E+10	1.06E+11	1.20E+12	7.83E+11	5.15E+09	9.35E+10	5.00E+12
5	1.52E+11	4.77E+10	1.80E+11	2.85E+12	1.80E+12	6.19E+09	1.96E+11	1.16E+13
6	1.50E+11	6.12E+10	2.46E+11	4.27E+12	2.50E+12	6.07E+09	2.96E+11	1.70E+13
7	1.30E+11	3.21E+10	8.93E+10	6.84E+11	4.21E+11	5.40E+09	6.15E+10	2.64E+12
8	1.02E+11	3.07E+10	9.44E+10	1.17E+12	7.64E+11	4.19E+09	8.32E+10	4.80E+12
9	1.34E+11	4.82E+10	1.59E+11	2.37E+12	1.41E+12	5.49E+09	1.76E+11	9.63E+12
10	8.32E+10	2.95E+10	9.31E+10	1.31E+12	7.69E+11	3.40E+09	9.81E+10	5.19E+12
11	9.71E+10	2.69E+10	1.11E+11	1.76E+12	1.13E+12	3.96E+09	1.23E+11	7.26E+12
12	1.14E+11	2.50E+10	1.30E+11	2.07E+12	1.21E+12	4.64E+09	1.51E+11	8.15E+12

Table I-9: South Run (VAN-A19R-04) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	7.58E+09	3.36E+08	1.54E+10	3.42E+11	1.60E+10	3.94E+08	3.38E+08	2.37E+09
2	6.25E+09	3.81E+08	1.46E+10	3.30E+11	1.49E+10	3.23E+08	3.23E+08	2.19E+09
3	8.41E+09	5.18E+08	1.63E+10	3.27E+11	1.58E+10	4.39E+08	3.27E+08	2.28E+09

Table I-9: South Run (VAN-A19R-04) Fecal Coliform Load: Existing Condition (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
4	6.52E+09	3.30E+08	9.63E+09	1.53E+11	7.69E+09	3.44E+08	1.63E+08	1.08E+09
5	7.91E+09	4.36E+08	1.64E+10	3.61E+11	1.76E+10	4.13E+08	3.41E+08	2.49E+09
6	7.85E+09	5.58E+08	2.23E+10	5.41E+11	2.45E+10	4.05E+08	5.15E+08	3.66E+09
7	6.77E+09	2.93E+08	8.12E+09	8.66E+10	4.14E+09	3.60E+08	1.07E+08	5.68E+08
8	5.30E+09	2.80E+08	8.58E+09	1.48E+11	7.50E+09	2.80E+08	1.45E+08	1.03E+09
9	7.01E+09	4.40E+08	1.45E+10	3.00E+11	1.38E+10	3.66E+08	3.06E+08	2.08E+09
10	4.34E+09	2.69E+08	8.46E+09	1.66E+11	7.55E+09	2.27E+08	1.71E+08	1.12E+09
11	5.06E+09	2.46E+08	1.01E+10	2.23E+11	1.11E+10	2.64E+08	2.14E+08	1.57E+09
12	5.94E+09	2.28E+08	1.18E+10	2.62E+11	1.19E+10	3.09E+08	2.62E+08	1.76E+09

H.2 Fecal Coliform Monthly Loads- Allocation Runs

Table I-10 Broad Run - 34 (VAN-A19R-01) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	2.04E+10	4.79E+09	3.56E+10	2.02E+11	7.01E+10	5.55E+08	6.48E+09	1.86E+11
2	1.68E+10	5.42E+09	3.39E+10	1.95E+11	6.52E+10	4.55E+08	6.20E+09	1.72E+11
3	2.26E+10	7.37E+09	3.79E+10	1.94E+11	6.88E+10	6.18E+08	6.29E+09	1.79E+11
4	1.75E+10	4.69E+09	2.24E+10	9.02E+10	3.36E+10	4.84E+08	3.12E+09	8.46E+10
5	2.12E+10	6.20E+09	3.81E+10	2.13E+11	7.70E+10	5.81E+08	6.56E+09	1.96E+11
6	2.11E+10	7.95E+09	5.18E+10	3.20E+11	1.07E+11	5.70E+08	9.89E+09	2.88E+11
7	1.82E+10	4.17E+09	1.88E+10	5.12E+10	1.81E+10	5.07E+08	2.05E+09	4.46E+10
8	1.42E+10	3.99E+09	1.99E+10	8.73E+10	3.27E+10	3.94E+08	2.78E+09	8.12E+10
9	1.88E+10	6.26E+09	3.36E+10	1.78E+11	6.04E+10	5.15E+08	5.87E+09	1.63E+11
10	1.17E+10	3.83E+09	1.96E+10	9.82E+10	3.30E+10	3.19E+08	3.28E+09	8.78E+10
11	1.36E+10	3.50E+09	2.35E+10	1.32E+11	4.86E+10	3.72E+08	4.10E+09	1.23E+11
12	1.60E+10	3.25E+09	2.73E+10	1.55E+11	5.20E+10	4.36E+08	5.04E+09	1.38E+11

Table I-11 Broad Run - 40 (VAN-A19R-02) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	3.89E+09	7.60E+08	5.27E+09	3.12E+10	3.08E+09	1.48E+07	1.39E+08	0.00E+00
2	3.21E+09	8.62E+08	5.02E+09	3.01E+10	2.86E+09	1.21E+07	1.33E+08	0.00E+00
3	4.31E+09	1.17E+09	5.61E+09	2.99E+10	3.02E+09	1.65E+07	1.35E+08	0.00E+00
4	3.34E+09	7.46E+08	3.31E+09	1.39E+10	1.48E+09	1.29E+07	6.69E+07	0.00E+00
5	4.06E+09	9.85E+08	5.63E+09	3.29E+10	3.39E+09	1.55E+07	1.40E+08	0.00E+00
6	4.03E+09	1.26E+09	7.66E+09	4.94E+10	4.71E+09	1.52E+07	2.12E+08	0.00E+00
7	3.48E+09	6.63E+08	2.79E+09	7.90E+09	7.94E+08	1.35E+07	4.40E+07	0.00E+00
8	2.72E+09	6.33E+08	2.95E+09	1.35E+10	1.44E+09	1.05E+07	5.95E+07	0.00E+00
9	3.60E+09	9.94E+08	4.97E+09	2.74E+10	2.65E+09	1.37E+07	1.26E+08	0.00E+00
10	2.23E+09	6.09E+08	2.90E+09	1.52E+10	1.45E+09	8.50E+06	7.02E+07	0.00E+00

Table I-11 Broad Run - 40 (VAN-A19R-02) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
11	2.60E+09	5.56E+08	3.48E+09	2.04E+10	2.14E+09	9.91E+06	8.78E+07	0.00E+00
12	3.05E+09	5.16E+08	4.04E+09	2.40E+10	2.28E+09	1.16E+07	1.08E+08	0.00E+00

Table I-12 Broad Run - 42 (VAN-A19R-05) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	1.77E+09	5.51E+08	5.05E+09	5.62E+09	2.10E+09	1.23E+06	0.00E+00	0.00E+00
2	1.46E+09	6.24E+08	4.80E+09	5.42E+09	1.95E+09	1.01E+06	0.00E+00	0.00E+00
3	1.97E+09	8.48E+08	5.37E+09	5.37E+09	2.06E+09	1.37E+06	0.00E+00	0.00E+00
4	1.52E+09	5.40E+08	3.17E+09	2.51E+09	1.01E+09	1.07E+06	0.00E+00	0.00E+00
5	1.85E+09	7.14E+08	5.39E+09	5.92E+09	2.31E+09	1.29E+06	0.00E+00	0.00E+00
6	1.84E+09	9.15E+08	7.34E+09	8.89E+09	3.21E+09	1.27E+06	0.00E+00	0.00E+00
7	1.58E+09	4.80E+08	2.67E+09	1.42E+09	5.41E+08	1.13E+06	0.00E+00	0.00E+00
8	1.24E+09	4.59E+08	2.82E+09	2.42E+09	9.81E+08	8.75E+05	0.00E+00	0.00E+00
9	1.64E+09	7.20E+08	4.76E+09	4.93E+09	1.81E+09	1.14E+06	0.00E+00	0.00E+00
10	1.02E+09	4.41E+08	2.78E+09	2.73E+09	9.87E+08	7.08E+05	0.00E+00	0.00E+00
11	1.18E+09	4.03E+08	3.33E+09	3.66E+09	1.46E+09	8.26E+05	0.00E+00	0.00E+00
12	1.39E+09	3.74E+08	3.87E+09	4.31E+09	1.56E+09	9.67E+05	0.00E+00	0.00E+00

Table I-13 Bull Run - 9 (VAN-A23R-01) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	2.23E+09	6.38E+06	4.48E+08	1.39E+11	4.65E+09	7.73E+07	1.48E+09	1.11E+11
2	1.83E+09	7.22E+06	4.27E+08	1.34E+11	4.33E+09	6.34E+07	1.41E+09	1.02E+11
3	2.47E+09	9.82E+06	4.77E+08	1.33E+11	4.57E+09	8.62E+07	1.43E+09	1.06E+11
4	1.91E+09	6.25E+06	2.81E+08	6.22E+10	2.23E+09	6.75E+07	7.12E+08	5.03E+10
5	2.32E+09	8.26E+06	4.79E+08	1.47E+11	5.11E+09	8.10E+07	1.49E+09	1.16E+11
6	2.30E+09	1.06E+07	6.52E+08	2.21E+11	7.11E+09	7.95E+07	2.25E+09	1.71E+11
7	1.99E+09	5.56E+06	2.37E+08	3.53E+10	1.20E+09	7.07E+07	4.68E+08	2.65E+10
8	1.56E+09	5.31E+06	2.50E+08	6.02E+10	2.17E+09	5.49E+07	6.34E+08	4.82E+10
9	2.06E+09	8.34E+06	4.23E+08	1.22E+11	4.01E+09	7.18E+07	1.34E+09	9.69E+10
10	1.27E+09	5.11E+06	2.47E+08	6.76E+10	2.19E+09	4.45E+07	7.47E+08	5.22E+10
11	1.49E+09	4.66E+06	2.96E+08	9.09E+10	3.23E+09	5.19E+07	9.35E+08	7.30E+10
12	1.75E+09	4.33E+06	3.44E+08	1.07E+11	3.45E+09	6.07E+07	1.15E+09	8.19E+10

Table I-14 Kettle Run (VAN-A19R-03) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	1.47E+09	1.15E+09	2.37E+09	3.23E+10	1.18E+09	1.53E+07	4.01E+08	1.57E+09
2	1.21E+09	1.31E+09	2.25E+09	3.12E+10	1.09E+09	1.25E+07	3.84E+08	1.45E+09
3	1.63E+09	1.77E+09	2.52E+09	3.09E+10	1.15E+09	1.70E+07	3.89E+08	1.51E+09
4	1.27E+09	1.13E+09	1.48E+09	1.44E+10	5.63E+08	1.33E+07	1.93E+08	7.15E+08
5	1.54E+09	1.49E+09	2.53E+09	3.41E+10	1.29E+09	1.60E+07	4.06E+08	1.65E+09
6	1.52E+09	1.91E+09	3.44E+09	5.11E+10	1.80E+09	1.57E+07	6.12E+08	2.43E+09
7	1.32E+09	1.00E+09	1.25E+09	8.18E+09	3.03E+08	1.40E+07	1.27E+08	3.77E+08

8	1.03E+09	9.60E+08	1.32E+09	1.39E+10	5.49E+08	1.08E+07	1.72E+08	6.86E+08
9	1.36E+09	1.51E+09	2.23E+09	2.84E+10	1.01E+09	1.42E+07	3.63E+08	1.38E+09
10	8.43E+08	9.23E+08	1.30E+09	1.57E+10	5.53E+08	8.78E+06	2.03E+08	7.42E+08
11	9.84E+08	8.42E+08	1.56E+09	2.11E+10	8.15E+08	1.02E+07	2.54E+08	1.04E+09
12	1.15E+09	7.82E+08	1.81E+09	2.48E+10	8.72E+08	1.20E+07	3.12E+08	1.16E+09

Table I-15 Little Bull Run (VAN-A21R-01) Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	3.74E+09	5.91E+08	3.93E+09	2.63E+10	5.04E+09	2.41E+07	2.32E+09	2.99E+10
2	3.09E+09	6.70E+08	3.74E+09	2.54E+10	4.69E+09	1.98E+07	2.22E+09	2.77E+10
3	4.15E+09	9.10E+08	4.18E+09	2.52E+10	4.95E+09	2.69E+07	2.25E+09	2.88E+10
4	3.22E+09	5.80E+08	2.46E+09	1.17E+10	2.42E+09	2.11E+07	1.12E+09	1.36E+10
5	3.91E+09	7.66E+08	4.20E+09	2.78E+10	5.54E+09	2.53E+07	2.35E+09	3.15E+10
6	3.88E+09	9.82E+08	5.71E+09	4.17E+10	7.71E+09	2.48E+07	3.54E+09	4.63E+10
7	3.35E+09	5.16E+08	2.08E+09	6.67E+09	1.30E+09	2.21E+07	7.36E+08	7.18E+09
8	2.62E+09	4.92E+08	2.20E+09	1.14E+10	2.36E+09	1.71E+07	9.96E+08	1.31E+10
9	3.46E+09	7.73E+08	3.71E+09	2.31E+10	4.35E+09	2.24E+07	2.10E+09	2.62E+10
10	2.14E+09	4.73E+08	2.17E+09	1.28E+10	2.37E+09	1.39E+07	1.17E+09	1.41E+10
11	2.50E+09	4.32E+08	2.59E+09	1.72E+10	3.50E+09	1.62E+07	1.47E+09	1.98E+10
12	2.94E+09	4.01E+08	3.02E+09	2.02E+10	3.74E+09	1.89E+07	1.80E+09	2.22E+10

Table I-16 Occoquan River (VAN-A20R-01) Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	2.02E+09	2.92E+08	7.85E+08	1.02E+11	1.17E+10	4.57E+07	1.67E+09	9.40E+10
2	1.66E+09	3.31E+08	7.47E+08	9.86E+10	1.09E+10	3.75E+07	1.59E+09	8.70E+10
3	2.23E+09	4.49E+08	8.35E+08	9.78E+10	1.15E+10	5.09E+07	1.62E+09	9.04E+10
4	1.73E+09	2.86E+08	4.92E+08	4.56E+10	5.61E+09	3.99E+07	8.03E+08	4.28E+10
5	2.10E+09	3.78E+08	8.39E+08	1.08E+11	1.29E+10	4.79E+07	1.68E+09	9.89E+10
6	2.09E+09	4.85E+08	1.14E+09	1.62E+11	1.79E+10	4.70E+07	2.54E+09	1.45E+11
7	1.80E+09	2.54E+08	4.15E+08	2.59E+10	3.02E+09	4.18E+07	5.28E+08	2.26E+10
8	1.41E+09	2.43E+08	4.39E+08	4.41E+10	5.47E+09	3.25E+07	7.14E+08	4.10E+10
9	1.86E+09	3.82E+08	7.40E+08	8.98E+10	1.01E+10	4.25E+07	1.51E+09	8.24E+10
10	1.15E+09	2.34E+08	4.33E+08	4.96E+10	5.51E+09	2.63E+07	8.42E+08	4.44E+10
11	1.35E+09	2.13E+08	5.18E+08	6.67E+10	8.12E+09	3.07E+07	1.05E+09	6.21E+10
12	1.58E+09	1.98E+08	6.03E+08	7.84E+10	8.68E+09	3.59E+07	1.29E+09	6.97E+10

Table I-17 Popes Head (VAN-A23R-02) Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	7.27E+09	1.84E+09	8.44E+09	1.35E+11	8.17E+10	2.95E+08	9.70E+09	5.50E+11
2	5.99E+09	2.09E+09	8.04E+09	1.30E+11	7.60E+10	2.42E+08	9.28E+09	5.09E+11
3	8.06E+09	2.84E+09	8.98E+09	1.29E+11	8.02E+10	3.29E+08	9.41E+09	5.29E+11
4	6.25E+09	1.81E+09	5.30E+09	6.02E+10	3.91E+10	2.58E+08	4.68E+09	2.50E+11
5	7.58E+09	2.39E+09	9.02E+09	1.42E+11	8.98E+10	3.09E+08	9.81E+09	5.78E+11
6	7.52E+09	3.06E+09	1.23E+10	2.14E+11	1.25E+11	3.04E+08	1.48E+10	8.50E+11
7	6.49E+09	1.61E+09	4.46E+09	3.42E+10	2.11E+10	2.70E+08	3.07E+09	1.32E+11

Table I-17 Popes Head (VAN-A23R-02) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
8	5.08E+09	1.53E+09	4.72E+09	5.83E+10	3.82E+10	2.10E+08	4.16E+09	2.40E+11
9	6.72E+09	2.41E+09	7.96E+09	1.19E+11	7.04E+10	2.74E+08	8.78E+09	4.82E+11
10	4.16E+09	1.48E+09	4.65E+09	6.55E+10	3.84E+10	1.70E+08	4.90E+09	2.59E+11
11	4.85E+09	1.35E+09	5.57E+09	8.80E+10	5.67E+10	1.98E+08	6.14E+09	3.63E+11
12	5.70E+09	1.25E+09	6.48E+09	1.04E+11	6.06E+10	2.32E+08	7.54E+09	4.07E+11

Table I-18: South Run (VAN-A19R-04) Fecal Coliform Load: Allocation Run (counts/ month)								
Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	Other Urban	High Density Residential
1	3.79E+08	1.68E+07	7.68E+08	1.71E+10	8.02E+08	1.97E+07	1.69E+07	1.18E+08
2	3.12E+08	1.90E+07	7.31E+08	1.65E+10	7.46E+08	1.61E+07	1.62E+07	1.10E+08
3	4.20E+08	2.59E+07	8.17E+08	1.64E+10	7.88E+08	2.20E+07	1.64E+07	1.14E+08
4	3.26E+08	1.65E+07	4.82E+08	7.63E+09	3.84E+08	1.72E+07	8.14E+06	5.39E+07
5	3.95E+08	2.18E+07	8.20E+08	1.80E+10	8.82E+08	2.06E+07	1.71E+07	1.25E+08
6	3.92E+08	2.79E+07	1.12E+09	2.71E+10	1.23E+09	2.03E+07	2.57E+07	1.83E+08
7	3.39E+08	1.47E+07	4.06E+08	4.33E+09	2.07E+08	1.80E+07	5.35E+06	2.84E+07
8	2.65E+08	1.40E+07	4.29E+08	7.38E+09	3.75E+08	1.40E+07	7.24E+06	5.17E+07
9	3.50E+08	2.20E+07	7.24E+08	1.50E+10	6.92E+08	1.83E+07	1.53E+07	1.04E+08
10	2.17E+08	1.35E+07	4.23E+08	8.30E+09	3.77E+08	1.13E+07	8.54E+06	5.59E+07
11	2.53E+08	1.23E+07	5.07E+08	1.11E+10	5.56E+08	1.32E+07	1.07E+07	7.83E+07
12	2.97E+08	1.14E+07	5.89E+08	1.31E+10	5.95E+08	1.55E+07	1.31E+07	8.78E+07